the glass industry
VOLUME 37, NUMBER 5, MAY, 1956

The Effect of Various Iron Compounds on the Transmission and Color of Soda-Lime-Silica Glass

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ABSTRACT

Iron was introduced into a standard glass cullet in various increments ranging from 0.1 per cent Fe to 1.6 per cent Fe. The standard glass was a window glass cullet of known composition and by its use, the variables introduced by raw batch melting were reduced. Three sources of iron were used, namely, electrolytic iron, magnetite, and red iron oxide. These materials were quite pure, and the analysis of each is given.

All glasses were melted in platinum crucibles on the same heating schedule to 2550° F. (1400° C.), after which they were poured and annealed. Each glass was analyzed for ferrous iron and total iron using ceric sulphate titration and ortho-phenanthrolein as an indicator. Spectral transmission curves were made of each sample from 310—1200mμ and the results correlated with the chemical analysis.

I. INTRODUCTION

Color contributed by iron in some form or other has been a subject of great importance to the glass technologist. Iron probably has the most widespread influence of all coloring constituents. However, it is not enough to consider the amount of iron alone: the state of oxidation, or reduction, is even more important.

The lower oxide of iron is accompanied by strong infra-red absorption by the glass so that the transfer of heat into the molten glass and the currents produced in a tank depend, to a considerable extent, on the iron content and its state of oxidation. Iron is also known to affect the time of working of a glass because high percentages of ferrous iron cause the glass to lose heat faster and therefore shorten the working time. The iron content has also caused disturbing changes in color in the lehr.

Hostetter and Roberts[1] have shown that in soda-lime-silica glasses, above 1300°C., ferric oxide is dissociated appreciably with the evolution of oxygen and the formation of the corresponding quantities of ferrous oxide. They found that dissociation of 10 per cent of ferric oxide produced a bright green color while a glass with dissociation of 4.1 per cent was yellow. They pointed out that iron compounds can be "reduced" by heating to a high temperature under oxidizing conditions.

Starkie and Turner[2] investigated the influence of ferrous oxide content on the light transmission of soda-lime-silica glasses. Some of their glasses contained 89 per cent ferrous oxide of the total iron present, calculated as ferric oxide. The iron content of the glasses varied from 0.005 per cent to 1.00 per cent. In ferric or highly oxidized glasses, the maximum transmission was at 550mμ corresponding to the yellow-green region of the spectrum. In the reduced glasses, the maximum transmission was at 480 mμ corresponding to the bluish-green region of the spectrum. The over-all absorption of the red rays by the ferrous glasses was considerably more than that of the ferric glasses.

K. Fuwa[3] studied very extensively the effect of adding different oxidizing and reducing agents in soda-lime-silica glasses containing iron. By adding 0.1 per cent to 6 per cent arsenic to the batch of a glass containing 72 per cent SiO_2, 10 per cent CaO, 2 per cent Fe_2O_3 and 16 per cent Na_2O, he observed that (1) an increasing amount of arsenic intensified the yellowish color of the glass slightly, (2) the ratio FeO to $FeO+Fe_2O_3$ in a glass remained almost constant for all amounts of arsenic, (3) the transmission curves of the specimens of the glasses intersected each other at about 510 mμ (4) the

shortest wave-length of rays transmitted by the glass moved towards a longer one as the amount of the oxide increased, while at the same time the transmission at 700 mμ increased.

Densem and Turner[4] investigated the equilibrium between ferrous and ferric oxides in soda-lime-silica glasses containing 0.002 to 12.5 per cent ferric oxide. The glasses were melted in an electric furnace at 1400 C. for 22 hours. The maximum dissociation of iron oxide occurred at a total iron oxide content of 0.04 per cent Fe_2O_3, namely, 36 per cent, and fell steadily until it reached a nearly constant value of about 9 per cent for iron oxide concentration between 3 and 12.5 per cent. They found that equilibrium between ferrous and ferric oxides depended on the temperature of melting, time of melting, concentration of iron, viscosity of the glass, general composition of the glass, and the influence of furnace atmosphere.

Using the same glasses as prepared by Densem and Turner[4], Wang and Turner[5] found that below 0.3 per cent of iron oxide there was a marked rise in the dissociation of Fe_2O_3 and that the increased FeO concentration was responsible for considerable absorption in the red region of the spectrum. The results indicated that low concentration of iron oxide, when completely in the ferric state, gave yellow or greenish-yellow color to the soda-lime-silica glasses. At high concentrations the ferric iron exercised high absorption, particularly in the blue-violet end, thus resulting in a brown or pale-brown color. At low concentrations, it was shown that ferrous iron bestowed a blue color on the glass.

Weyl[6] has postulated that the trivalent iron can participate in the structure of a glass in two ways. "It can be a network-former as well as network-modifier. As the former it creates FeO_4 corresponding to SiO_4 tetrahedra and as the latter it forms cations filling some of the interstitial holes of the silica network, where it is surrounded by a large number of oxygen atoms, maybe 6 or more. In such surrounding the ferric ion is practically colorless, whereas, when the coordination number is 4, it has strong absorption in the ultra-violet region which extends into the blue, so that brown colors result." According to him, the blue color in iron glasses "involves the existence of the two states of valency or the simultaneous presence of FeO and Fe_2O_3." The ferrous iron always exists in the glasses as a network-modifier. He also expressed the opinion that glasses containing only FeO may be colorless.

Recently, Moore and Prasad[7] concluded from their investigation that the effect of iron in glasses was due to iron in all three states of oxidation, namely: ferrous iron, giving a rich blue color; ferric iron, giving a rich amber; and ferroso-ferric iron, giving an almost perfectly "neutral gray." They indicated that ferric iron can also exist in "colorless" form in the glasses and "the most probable condition of the colorless iron is that it exists as ferric iron atoms, each linked to corners of three adjacent SiO_4 tetrahedra in the glass structure."

More recent work by Abou-El-Azur[8] summarized very extensive work related to the color produced by iron in various glasses as well as the color given by iron in its different structural state. According to Abou-El-Azur, iron may exist in five states in glasses:

(a) The ferrous iron giving the blue color may exist as ferrous ions enclosed within interstices in the glass structure. Each ferrous ion would normally be surrounded by six oxygen ions.

(b) The grey ferroso-ferric form of iron may exist as ferroso-ferric oxide colloidally dispersed in the glass.

(c) The brown form of iron may exist as ferric oxide colloidally dispersed in the glass.

(d) The colorless iron may exist as FeO_4 structure-building units in the glass structure, between other structure-building units of SiO_4, BO_3, etc. types.

(e) The form of iron which gives the pink color may exist as FeO_3 triangles, and since the value of magnetic susceptibility indicates that the iron is covalently linked to three oxygen ions surrounding it, these FeO_3 groups will act as structure-building units similar to BO_3 triangles.

The present investigation was limited to a soda-lime-silica glass only and interest was confined to the colors produced by varying sources of iron when the glass was melted under controlled conditions.

A study was made of the effect of increasing iron additions on the ferrous iron content of the glass as well as the effect of different sources of iron. In order to reduce the number of variables that might alter the state of iron in the fused glass, all melts were made by adding iron to a glass cullet of known composition. In this manner, the variable effects of raw batch were eliminated, e.g. the nitrates, sulfates, borates, carbonates, fluorides, etc. All fusions were made in platinum crucibles in order to reduce the influence of refractory contamination. The melts were also made in a globar heated furnace at the same temperature and for the same time interval. At least under the conditions of the experiment, many factors were held constant that otherwise might have influenced the final condition and state of iron in the glass.

II. EXPERIMENTAL WORK

A. Preparation of Samples

Thirty-four samples were prepared (including the standard glass which contained no additions of iron) in 3 series with 11 samples in each series. Electrolytic iron, red iron oxide, and magnetite were used respectively as sources of iron for the 3 series. The composition of the glass cullet and the three sources of iron used in the experiments are given in Section B. The iron impurities were added in each series in increments of 0.1 per cent in the range of 0.1 per cent to 0.6 per cent Fe, and in increments of 0.2 per cent in the range of 0.6 per cent to 1.6 per cent Fe (See Table I).

The composition of glass used was that of a window glass. It was ground to 80 mesh and thoroughly mixed with the iron impurity, prior to fusion. The samples were then melted in platinum crucibles in a Harper furnace on a 7-hour schedule to a temperature of 2550°F. (1400°C) and were held at that temperature for 2 hours before pouring. Two samples were prepared from each composition, one for chemical analysis and the other for transmission tests.

Each sample was annealed at 500°C. for one hour and then allowed to cool slowly to room temperature before it was taken from the lehr.

B. Composition of Raw Materials

(1) Glass Cullet (window glass) obtained from Commercial Plant

SiO_2	72.02%
Fe_2O_3	0.04
Al_2O_3	1.46
CaO	7.07
MgO	4.33
Na_2O	14.34
K_2O	0.36
SO_3	0.21
	99.83

( ) Electrolytic iron (No. 6248) Plastic Metals Inc., Johnstown, Pennsylvania

Total iron (Fe)	99.910%
Total carbon	0.015
Mn	0.007
P	0.004
Si	0.007
S	0.008
Others (difference)	0.049
	100.000

( ) Red Iron Oxide (Fe_2O_3) Chemical Reagent Technical Grade

Ferric oxide	98.8
SiO_2	0.4
H_2O	0.5
Moisture at 1100° C.	0.2
	99.9

(4) Magnetite (Fe_3O_4) No. 29a (Iron ore) Standard Sample 29a, National Bureau of Standards, Washington, D. C.

SiO_2	2.36
Al_2O_3	0.46
TiO_2	0.15
Fe (Total)	69.54
FeO	28.10
Fe_2O_3	68.20
Cr_2O_3	0.002
V_2O_3	0.002
MnO	0.030
CaO	0.096
MgO	0.095
P_2O_5	0.007
	100.002

C. Method of Chemical Anlysis of Glasses

The glasses used for chemical analyses were ground to 80 mesh.

0.01 N ceric sulfate was used for oxidizing Fe^{2+} to Fe^{3+} with ortho-phenanthrolein as indicator.

The analyses were made in a closed system, following two separate steps: (1) determination of ferrous iron content of the sample and (2) determination of total iron of the glass after all the iron had been reduced by stannous chloride.

In the ferrous iron analysis a one gram sample of glass was carefully weighed out and transferred to a clean 500 ml. "Pyrex" Ehrlenmeyer flask, 50 ml. of boiled 6N HCl were added, CO_2 was immediately passed into the flask, and then 20 ml. of boiled 48 per cent hydrofluoric acid were added. Ten minutes were allowed for the glass to dissolve while the flask was being swirled. Five grams of boric acid in 75 ml.. of boiled water solution were then poured into the flask to neutralize the excess HF (this was done to prevent the HF from destroying the indicator by forming HBF_4). The solution was then allowed to cool to room temperature, the flask being kept closed until the completion of the titration. A color change from orange to green was indicative of the end point.

For the determination of total iron, the ferric iron had to be reduced to the ferrous state. The same amounts of glass, acids, and boric acid were added. After the addition of boric acid, the solution was allowed to cool to room temperature. Stannous chloride was added to the solution drop by drop until the color of the solution changed from green to colorless. An extra drop or two were then added. The excess stannous chloride was

Table I. Iron Analysis of Various Glasses

G_1 Series – Electrolytic Iron Additions

Sample	Total Fe Calculated From Batch %	Total Fe Analyzed %	Difference %	Ferrous Iron Fe++ %	FeO Calculated From Analysis %	Fe_2O_3 Calculated From Analysis %	Ferrous State of Iron Fe++ x 100 / Total Iron (Fe++ x Fe+++) %
G_1 –1	0.1	0.125	.025	.025	.032	.143	18.4
G_1 –2	0.2	0.207	.007	.061	.078	.209	29.4
G_1 –3	0.3	0.265	–.035	.069	.089	.280	26.0
G_1 –4	0.4	0.470	.070	.110	.142	.515	23.4
G_1 –5	0.5	0.490	–.01	.132	.170	.512	27.0
G_1 –6	0.6	0.610	.01	.154	.198	.652	25.2
G_1 –8	0.8	0.940	.14	.193	.248	1.07	20.5
G_1 –10	1.0	1.06	.06	.255	.328	1.15	24.1
G_1 –12	1.2	1.32	.12	.272	.350	1.50	20.6
G_1 –14	1.4	1.50	.10	.298	.384	1.72	19.9
G_1 –16	1.6	1.67	.07	.334	.430	1.91	20.0

removed by the addition of saturated $HgCl_2$ until a white silky precipitate was observed. If the precipitate turned black, it indicated that the $SnCl_2$ had been added in too great excess and that the determination should be repeated. CO_2 was then passed into the flask after the reducing of Fe^{3+} to Fe^{2+} and the titration carried to completion.

The reagent $CeSO_4$ was prepared in the following manner:

For 0.1 N Ceric Sulfate, 109.6516 grams of 100 per cent $(NH_4)_2\ Ce(NO_3)_6$ were weighed out. To this amount were added 56 ml. of conc. H_2SO_4. The solution was stirred one half hour to release NO_2. The cake-like mass was then dissolved in distilled water to make 2 liters of approximately 0.1N $Ce(SO_4)_2$. The conc. H_2SO_4 was used because the reaction between dil. H_2SO_4 and $(NH_4)_2\ Ce(NO_3)_6$ does not result in a soluble sulfate compound.

The prepared $Ce(SO_4)_2$ solution was standardized against pure metallic iron wire. The iron wire was dissolved in 6N HCl. and reduced to Fe^{2+} by pouring it through a silver reductor. Ortho-phenanthrolein was used as an indicator. Completion of oxidation was marked by a change of color from orange to green. The standardized $Ce(SO_4)_2$ solution used was 0.0942 N.

0.01 N $Ce(SO_4)_2$ was prepared by diluting this standard solution with 2 per cent H_2SO_4 solution.

The analyses of the various glasses produced are shown in Table I. (See below and previous page.)

D. Spectral Transmission of Glass Samples

Samples of each glass given in Table I, approximately one inch in diameter, were ground and polished to about 1 mm. thickness. The spectral transmission of each was determined from approximately 310mμ to 1200mμ by means of a Beckman Spectrophotometer. The transmission data are presented in the following graphs: (See opposite page.)

G_1 Series (containing Electrolytic Iron)
G_2 Series (containing Red Iron Oxide (Fe_2O_3)
G_3 Series (containing Magnetite (Fe_3O_4)

(*Continued on page 2*:0)

Table I. Iron Analysis of Various Glasses

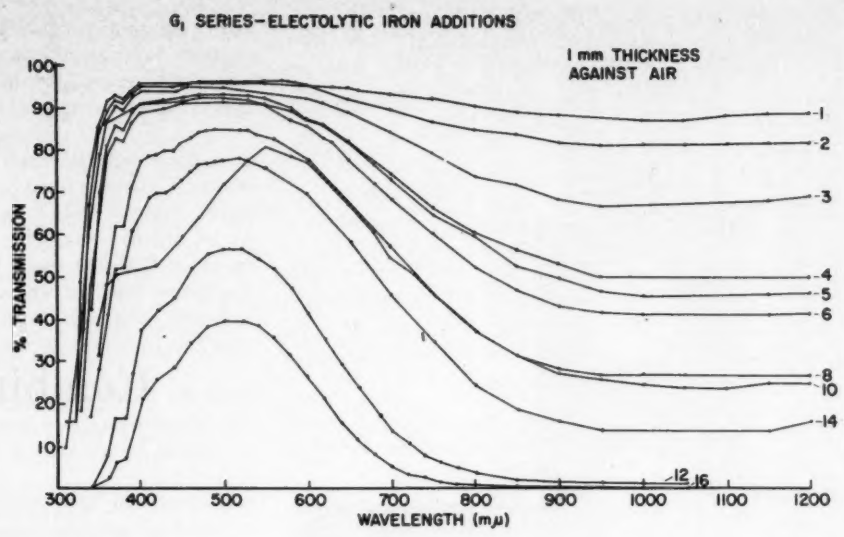
G_2 Series – Red Iron Oxide (Fe_2O_3) Additions

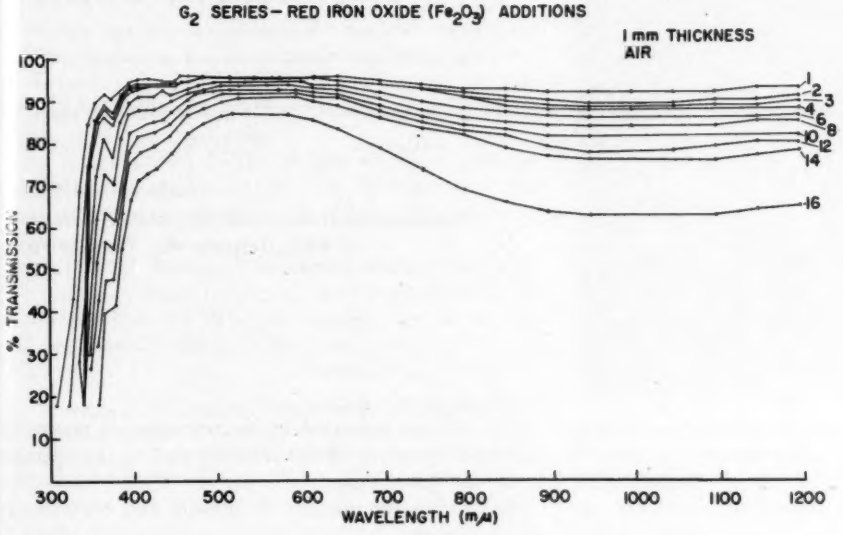
Sample	Total Fe Calculated From Batch %	Total Fe Analyzed %	Difference %	Ferrous Iron Fe++ %	FeO Calculated From Analysis %	Fe_2O_3 Calculated From Analysis %	Ferrous State of Iron Fe++ x 100 / Total Iron (Fe++ x Fe+++) %
G_2 –1	0.1	0.101	.001	.012	.015	.127	11.9
G_2 –2	0.2	0.19	–.01	.016	.020	.249	8.42
G_2 –3	0.3	0.30	.00	.022	.028	.398	7.35
G_2 –4	0.4	0.396	–.004	.027	.035	.528	6.82
G_2 –5	0.5	0.485	–.015	.033	.042	.647	6.80
G_2 –6	0.6	0.590	–.01	.038	.049	.789	6.44
G_2 –8	0.8	0.792	–.008	.048	.062	1.06	6.06
G_2 –10	1.0	0.993	–.007	.057	.073	1.34	5.75
G_2 –12	1.2	1.19	–.01	.067	.086	1.61	5.63
G_2 –14	1.4	1.39	–.01	.075	.096	1.88	5.40
G_2 –16	1.6	1.61	–.01	.117	.150	2.14	7.25

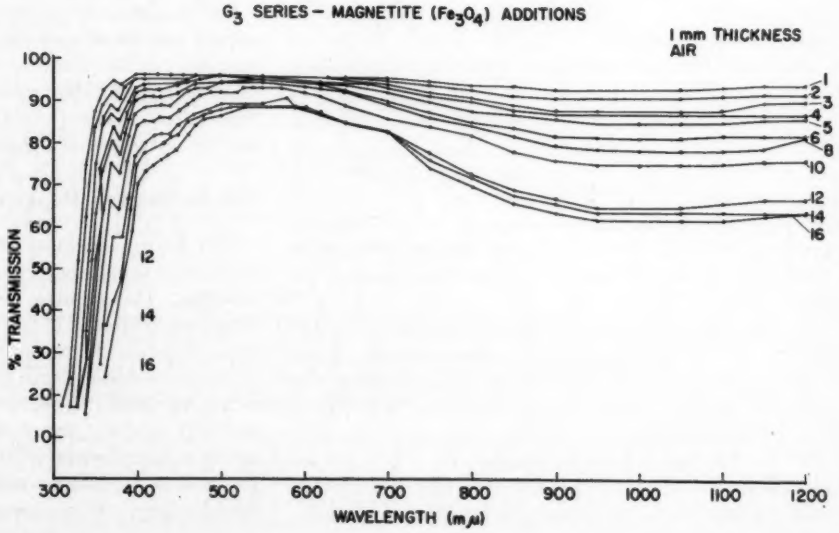
Table I. Iron Analysis of Various Glasses

G_3 Series – Magnetite (Fe_3O_4) Additions

Sample	Total Fe Calculated From Batch %	Total Fe Analyzed %	Difference %	Ferrous Iron Fe++ %	FeO Calculated From Analysis %	Fe_2O_3 Calculated From Analysis %	Ferrous State of Iron Fe++ x 100 / Total Iron (Fe++ x Fe+++) %
G_3 –1	0.1	0.10	0.0	.011	.014	.127	11.0
G_3 –2	0.2	0.192	–.008	.016	.021	.252	8.34
G_3 –3	0.3	0.30	0.0	.025	.032	.394	8.35
G_3 –4	0.4	0.393	–.007	.032	.041	.516	8.15
G_3 –5	0.5	0.497	–.003	.041	.053	.653	8.25
G_3 –6	0.6	0.590	–.01	.047	.060	.777	7.96
G_3 –8	0.8	0.790	–.01	.062	.080	1.04	7.85
G_3 –10	1.0	0.995	–.005	.076	.098	1.31	7.63
G_3 –12	1.2	1.22	.02	.118	.152	1.57	9.68
G_3 –14	1.4	1.38	–.02	.111	.143	1.81	8.03
G_3 –16	1.6	1.55	–.05	.106	.136	2.06	6.85


G1 SERIES–ELECTOLYTIC IRON ADDITIONS
1 mm THICKNESS
AGAINST AIR
% TRANSMISSION
WAVELENGTH (mμ)
1
2
3
4
5
6
8
10
12
14
16


G2 SERIES– RED IRON OXIDE (Fe2O3) ADDITIONS
1 mm THICKNESS
AIR
% TRANSMISSION
WAVELENGTH (mμ)
1
2
3
4
6
8
10
12
14
16


G3 SERIES– MAGNETITE (Fe3O4) ADDITIONS
1 mm THICKNESS
AIR
% TRANSMISSION
WAVELENGTH (mμ)
1
2
3
4
5
6
8
10
12
14
16

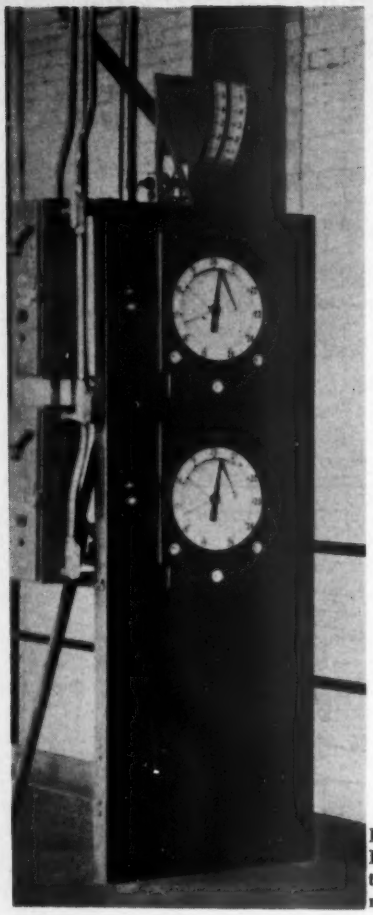


Fig. 1. Panel with Forehearth Temperature Control instruments installed.

Combined Approach To Better Forehearth Control

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● THE GLASS INDUSTRY DEPENDS heavily upon automatic temperature control systems for economical forehearth operation. When expansion and increased production rates in recent years absorbed the supply of experienced personnel and new machine operators could not be trained fast enough to meet the demand, container and pressed ware plants were quick to apply these automatic systems which have become almost indispensable to modern forehearth operation.

There are several significant advantages to automatic forehearth temperature control systems. They:

(1) Keep the temperature of all sections of the forehearth constant at all times.

(2) Reduce to an absolute minimum the need for manual weight changes by the operators.

(3) Allow the operator to make very minute temperature changes in the spout or channel section without undershooting or overshooting the desired temperature set point.

(4) Can save production time and output on a job change. If, before the change is started, the set point of the controller is reset for the new temperature, the controller will line out at the new set point by the time the job change has been completed.

(5) Secure higher machine speeds.

(6) Free the machine operator for other duties—his continual attention to the proper temperature of the forehearth sections is not necessary.

(7) Indicate immediately the minimum or maximum fuel input by means of signal lights, alerting the operator to unstable conditions.

(8) Permit the operator to quickly and conveniently switch to manual control, when necessary and return to automatic control without upsets.

The increase in production and percentage of ware packed associated with the use of forehearth control systems has resulted from the combined efforts of the instrument department, the forming department and the furnace department. Only through inter-departmental cooperation can such systems operate at their maximum efficiency.

The Instrument Department's Contribution

It is the responsibility of the instrument department to keep the instruments in first class operating condition at all times. This requires proper installation initially and, thereafter, periodic checking of all components at frequent intervals.

To reduce maintenance shutdowns the controller should be located where it will be relatively free from dust, oil and high ambient temperature. Proper air purging of radiation pyrometers is very important and should be provided in accordance with the recommendations of the manufacturer. If a pneumatic control system is used,

clean, dry air, delivered to the instrument at the proper pressure, is a *must*. All piping must be checked carefully for leaks. The use of a conditioning system for instrument air, such as that shown schematically in the accompanying illustration, is recommended.

The control valve is one of the most vital components of the forehearth temperature control system. Upon installation, the linkage should be checked to make certain that friction is not excessive. The valve should be adjusted to operate over its full travel with a 3 to 15 psi change in air pressure. This adjustment will permit sufficiently small movements of the valve between minimum and maximum fuel input to prevent oscillation and overshooting the set point.

The valve should be properly lubricated at all times. Frequency of lubrication depends to a great extent upon the valve's location, but in any event it should be checked every six months.

In addition to proper installation and maintenance of the control system, the instrument department should be responsible for instructing the machine operator in the proper use of the equipment. The system is expensive; its primary purpose is to relieve the machine operator of the time-consuming job of manually regulating the forehearth temperature, and unless he understands the system's capabilities and limitations, the investment in equipment is never fully realized.

The instrument department should, therefore, give the operator a simplified explanation of the instrument and associated equipment so that he will be able to use it intelligently.

Also, through the use of instrument charts, this department can contribute further to the operator's training by showing him the effect of improper use of cooling wind or improper setting of the stack covers.

(*Continued on page* 278)

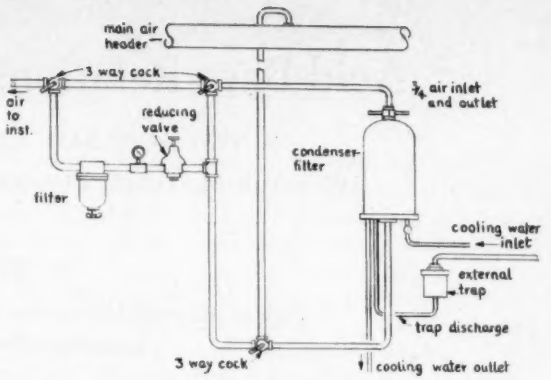


Fig. 3. Instrument air conditioning system recommended for proper operation of pneumatic controllers in glass plants.

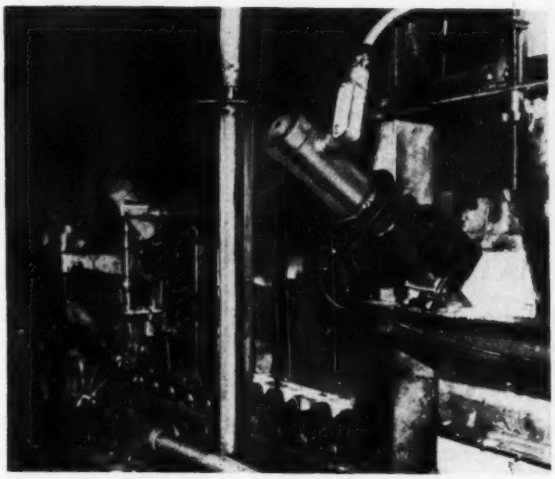
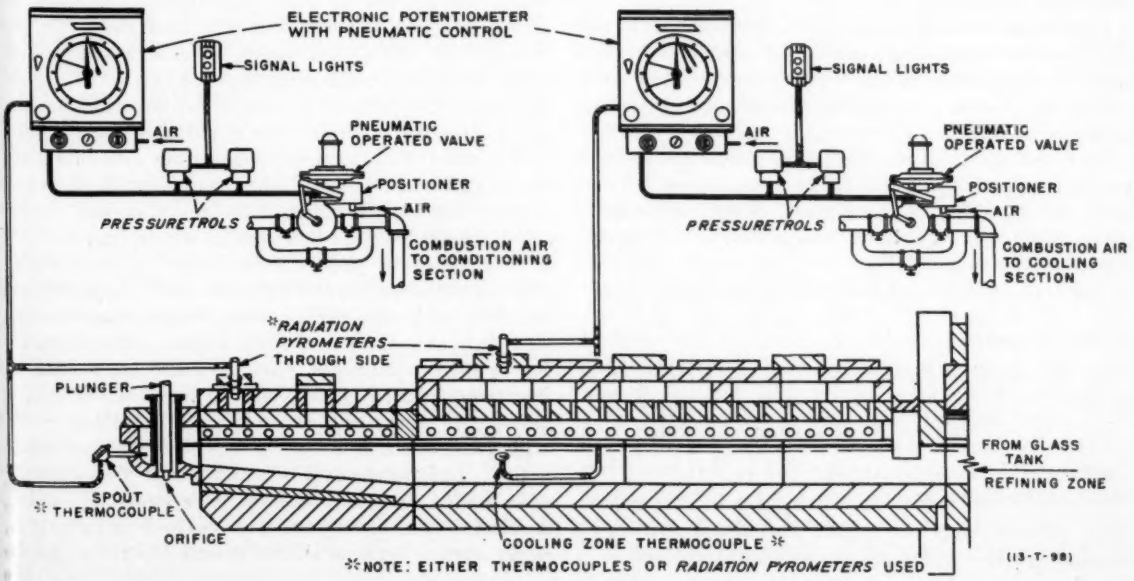


Fig. 4. Radiation pyrometer installation for cooling and conditioning zone temperature measurement. These units are installed at an angle through the side of the forehearth structure.

Fig. 2. (Below) Forehearth Temperature Control System, shown schematically. Pneumatic controllers are illustrated. Temperature can be measured with either thermocouples or radiation pyrometers.



Acid-Base Relationship in Glass Systems

A NEW ACID-BASE CONCEPT APPLICABLE TO AQUEOUS SYSTEMS, FUSED SALTS, GLASSES, AND SOLIDS

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Preface

The acidity of glasses is a concept which has become of considerable interest because one has learned to associate certain properties with it. Acid glasses, as a rule, are more stable with respect to weathering and devitrification. Increasing the basicity makes a glass more fluid but leads to devitrification and produces poor chemical resistivity. Refractory attack, too, is closely related to the acidity of a glass.

In a series of three papers, W. A. Weyl and associates will present a new approach to the acid-base concept which is applicable to aqueous solutions, fused salts, slags, and glasses. A sodium silicate glass would be useless as a window pane even if it contains as much as 85 per cent silica. Replacing 15 per cent silica by lime produces a useful glass. This has been known for centuries but has never been explained. Weyl and his associates present an explanation and a method for experimentally evaluating acidity.

The first installment of Part I in this series follows:

I. Introduction

La definition de l'acide est á vrai dire la clef de la chimie. Guyton de Morveau 1786

These words of Guyton de Morveau fit present day chemistry just as much as they did at the time when chemistry became a science. The history of the acid-base concept shows the struggle of scientists to penetrate into nature's secrets. This struggle is not yet over. On the contrary, one may say that it became more tense when the interest in non-aqueous solvents and the large scale use of the alumina-silica catalyst, a proton-donating or acid solid, called for new definitions of acids.

Most of us will agree with G. de Morveau that an understanding of acidity and basicity should provide a key to the understanding of chemistry. This must lead us to the conclusion that there can be no better proving ground for evaluating a new approach to chemical binding than to find out how this new concept can be applied to acids, bases, and to salt formation.

The author developed an atomistic concept of chemical reactions and their activation energies primarily in order to further solid state and high temperature chemistry. This concept, the "screening theory," was found to be of a much more general applicability than originally planned. In order to give those chemists who are less versed in high temperature chemistry a chance to evaluate this concept, we shall apply the screening theory to acids, bases, and salt formation: first to aqueous systems and then to fused salts and glasses.

Before developing a definition of acids and bases which can be used in high temperatutre chemistry we should examine whether or not a need exists for the terminology "acids" and "bases." Such an examination would probably lead to the conclusion that from a scientific point of view there is no need for the acid-base concept. As a matter of fact, we would find that the acid-base concept is not only superfluous but also confusing. From a practical point of view, however, the acid-base concept has been established for centuries and its use must have its merits. It would be utterly impossible to convince glass or cement technologists or metallurgists that in glasses, slags and other oxide systems one does not deal with acidic and basic oxides. Basic furnace linings, acid slags, etc., are concepts which have a definite meaning in these technologies. Acidic, basic, and neutral refractories are used in metallurgical furnaces. A neutral graphite or chromite lining cannot be replaced by an acid refractory (silica) or by a basic refractory (magnesia). Unfortunately, it is impossible to give a precise definition of acids and bases as these terms are used in the chemistry of glasses and slags. Above all there is no direct relation between an acidic melt of oxides and the

Work sponsored by the Office of Naval Research under Contract N6 onr 269 Task Order 8, NR 032-264, The Pennsylvania State University, University Park, Pa. Mineral Industries Contribution No. 55-58.

acidity of aqueous solutions. The very acidic melts must be considered basic when compared with neutral water.

When an operator of a furnace talks about the furnace temperature he uses the words "hot" and "cold" in the same way as when one talks about the weather. Without further specification those people who are concerned know what the furnace temperature should be just as they know what kind of weather was to be expected at this time of the year and at this particular place. In the same way it is convenient to talk about acidic and basic slags and refractories.

In quantitative decriptions of the temperature one uses a zero point which is chosen arbitrarily so that the most commonly used temperature scales include positive and negative values. If we want to understand physical and chemical laws, for example, if we want to find out how a change of the temperature affects the volume of a gas or the rate of a chemical reaction, we have to abandon our inherited, illogical temperature scale. Thermodynamic laws become simpler if one uses the absolute scale expressing the temperaure in degrees Kelvin rather than in degrees Celsius, Fahrenheit or Reaumur.

Apparently nobody has ever argued seriously about the definition of "hot" and "cold," but ever since chemistry became a science chemists have struggled for a definition of "acids" and "bases." Everything seemed so clear when S. Arrhenius defined acids as molecules which produce protons in aqueous solution. Practical reasons were responsible for the general acception of the Arrhenius' definition, but it is neither logical nor scientific to use water as a reference just because it is so abundant.

In teaching chemistry one usually introduces the acid-base concept by presenting its historical development. The different interpretations of acidity, basicity and salt formation are given to the student side by side and most text books avoid a preference for one particular concept.

The first concise definition of an acid as a hydrogen compound which produces hydrogen ions in water (S. Arrhenius) is still sufficient for most purposes, e.g., the titrations of acids and bases in aqueous solutions. The fact that the infrared spectra and the Raman spectra of aqueous solutions do not reveal the presence of the hypothetical hydrogen and hydroxyl ions in a free or hydrated state does not impair the usefulness of this concept.

For a more quantitative treatment the extension of the Arrhenius concept by J. N. Broensted (1923) and T. M. Lowry (1923) offers a decided advantage. An acid is defined as a substance which is capable of releasing protons provided that there is another molecule (base) available which can accept the proton. Acid-base reactions are treated as competitions for protons. Water is no longer an essential factor in this concept. Salt formation, e.g.,

$$NH_3 + HCl = NH_4Cl,$$

can take place in any liquid as well as in the gas phase.

Abandoning water as a reference is important if one wants to extend the acid-base concept to non-aqueous solvents. Furthermore, it becomes evident that in those reactions in which water participates, the water plays a role which goes beyond that of a solvent. Water can behave as an acid or as a base depending on the molecular species with which it interacts. Thus, water is an acid with respect to molecules which can accept protons, e.g., NH_3,

$$NH_3 + H_2O = NH_4^+ + OH^-$$

but it becomes a base with respect to molecules which have a tendency to release a proton:

$$HCl + H_2O = Cl^- + H_3O^+$$

The phenomenon of hydrolysis of salts, e.g., $AlCl_3$ and Na_2CO_3, becomes understandable when one refers to water as a potential base or a potential acid rather than as a liquid which ionizes these compounds and solvates the ions.

The leveling effect of water upon strong acids and upon strong bases which could not be understood on the basis of the Arrhenius concept became understandable on the basis of the Broensted-Lowry concept. The chief limitation of this concept is its dependence upon the proton: a limitation, however, which does not affect the majority of chemists. For solid state chemistry, as well as for the chemistry of fused salts, one cannot use a concept which is centered around the proton.

The G. N. Lewis concept of acid-base reactions which involves the formation of a covalent coordinate bond between two atoms cannot be applied to systems which are ionic. The Lewis concept defines acids as molecules which contain atoms with incomplete electronic shells and bases as molecules which contain atoms which can donate electron pairs. This concept makes it difficult to emphasize one of the main features of the acid-base concept, namely, that it is only relative. Even a strong acid, e.g., HNO_3, can become a base with respect to a stronger acid, namely, perchloric acid. Silica can be called an acid with respect to BaO but it is a base when it reacts with P_2O_5 and forms silicylphosphate. Furthermore, the concept of the completion of an electron shell and the formation of a covalent bond cannot take into consideration electrostatic interactions of ions and, as a result, it cannot lead to an energy term which can be interpreted as "acid strength." A HCl molecule, for example, dissolved in chloroform is a weaker acid than a HBr molecule because the greater electrostatic attraction between H^+ and Cl^- makes it more difficult to remove a proton from the small Cl^- than from the larger Br^- ion. Such a difference between two molecules cannot be anticipated on the basis of the Lewis concept and it is so important in chemistry. Olefins, for example, react fastest with elemental chlorine, slower with bromine, and slowest with iodine. The addition reactions of HCl, HBr, and HI follow just the opposite trend because the rate determining step is the removal of a proton from the electron clouds of the Cl^-, Br^-, and I^- ions and this process requires least energy for HI because the Coulombic forces decrease with the size of the anion.

As far as the usefulness of the different concepts is concerned, the author shares the opinion of L. F. Audrieth who concluded his Priestley Lecture (1949) with the words: "The solvent system concept, the protonic theory, and the Lewis definition are all useful word pictures. Each of them will continue for some time to serve as useful guides to further advance chemical science and stimulate academic and industrial research activities."

It is important, indeed, that we realize that these definitions are word pictures but not explanations. This is clearly expressed by J. A. A. Ketelaar when he refers to acidity in the introduction of his book "Chemical

Constitution" (1953). He uses the decreasing acidity of the molecules H_2SO_4, C_6H_5OH, C_2H_5OH, etc., as an example for the present difficulty to give an atomistic explanation for the widely different dissociation constants of these and similar molecules. He writes: "The first step in the right direction is made when it is realized that the question as to the essential 'why' of the chemical properties and reactions is significant, even though the complete answer may hardly ever be obtained."

II. Acidity and Basicity of Aqueous Solutions in the Light of the Screening Theory

The screening theory[1] provides a different approach to this problem and permits a new interpretation of acidity and basicity. The stability and the chemical inertness of the molecule SF_6 were attributed to the fact that the core of this molecule is completely screened when surrounded symmetrically by six anions. In contrast to the chemically inert SF_6 molecule, the molecules of SO_3 can polymerize because three anions are not sufficient to screen the S^{6+} core. Polymerization permits an increase of the coordination* through sharing of anions. In the presence of other molecules, e.g., CaO, which contain more polarizable O^{2-} ions, the SO_3 does not polymerize because it becomes energetically more favorable to react under salt formation:

$$CaO + SO_3 = CaSO_4$$

This type of salt formation can be described in two ways, depending upon the ion on which we focus our attention, namely,

(a) as a process in which molecules containing insufficiently screened cores (SO_3) improve their screening by expanding the coordination using anions of molecules which contain cations of lower field strength (CaO), or

(b) as a process in which molecules interact in order to equalize the state of polarization of their anions. Salt formation is a reaction which tightens the electron cloud of the anion of the base (CaO) and loosens the anions of the acid (SO_3).

This approach to the problems of acidity based on K. Fajans' ideas on the nature of chemical binding forces[2] has the advantage of great simplicity and general applicability. The screening theory does not link acidity to any particular cation nor does it require a solvent. The acidity of a system is treated as a property which is inversely proportional to the degree to which its cations are screened. Complete screening, as can be found in molecules such as CCl_4 or SF_6, means zero acidity. The demand of a molecule for additional screening can approach zero but it cannot have a negative value.

Our definition of acidity compares with that of the absolute temperature scale which starts with absolute zero and has no negative values. If it is desirable to introduce the concept of bases, one has to arbitrarily fix a neutral point just as one has to have an arbitrary reference temperature if one wants to speak of hot and cold. This is exactly what the different technologies have done. When glass technology became a science, a "normal glass" was chosen as a standard: Na_2O, CaO, 6 SiO_2. Glasses with higher silica content were called "acidic" and those with lower silica content were called "basic."

*The term "coordination" is used here in the way it is used in crystal structures, namely, designating the number of anions which screen a certain cation.

In aqueous chemistry the acidity of water was arbitrarily fixed as a neutral point. Water soluble substances can be neutral, acidic or basic. Oxides which introduce O^{2-} ions of greater polarizability than those of pure water are basic. Oxides which introduce O^{2-} ions of lower polarizability are acids. The strongly exothermic reactions of water with P_2O_5 or with K_2O can be described as processes which tend to equalize the state of polarization of all anions; the O^{2-} ions of the water and those of the P_2O_5 and of the K_2O.

(1) The Cationic Approach

In order to apply the screening concept to the acid-base relation as it exists in aqueous solutions, we substitute various cations for the equivalent number of protons (Table I).

(a) *Effect of Charge and Size of Noble Gas-Type Ions*

Among the different O^{2-} ions the most polarizable and also the least stable one is the one which is neutralized by the cation with the weakest field, the Cs^+ ion. Substitution of a Cs^+ ion for a proton leads to an aqueous solution of CsOH, i.e., the strongest base. The basicity of solutions of the alkali oxides decreases with increasing field strength, i.e., from CsOH to LiOH.

TABLE I

Change of the Acidity of Water by Cations of Increasing Charge and Identical Electron Configuration (Ne-Type)

H_2O	H_{2n}^{+}		O_n^{2-}	neutral
NaOH	H_{2n-1}^{+}	Na^+	O_n^{2-}	strong base
$Mg(OH)_2$	H_{2n-2}^{+}	Mg^{2+}	O_n^{2-}	weak base
$Al(OH)_3$	H_{2n-3}^{+}	Al^{3+}	O_n^{2-}	amphoteric
$Si(OH)_4$	H_{2n-4}^{+}	Si^{4+}	O_n^{2-}	weak acid
H_3PO_4	H_{2n-5}^{+}	P^{5+}	O_n^{2-}	stronger acid
H_2SO_4	H_{2n-6}^{+}	S^{6+}	O_n^{2-}	strong acid
$HClO_4$	H_{2n-7}^{+}	Cl^{7+}	O_n^{2-}	strongest acid

The least polarizable O^{2-} ions are those which are tightened and neutralized by positive cores with a very high field strength, such as Cl^{7+} ions. For this reason $HClO_4$ is a very strong acid. In the anion $(ClO_4)^-$ the O^{2-} ions are strongly deformed, i.e., their electron density is high toward the neon-like Cl^{7+} core so that the anion $(ClO_4)^-$ has a very low polarizability. For this reason perchlorates are chosen whenever one wants to keep the mutual polarization of ions at a minimum. For example, in crystal chemistry the Tl^+ ion is given the ionic radius of the Rb^+ ion because the compounds $TlClO_4$ and $RbClO_4$ have identical cell dimensions. In combination with anions which are more polarizable than the $(ClO_4)^-$ ion, Tl^+ ions cannot be compared with other noble gas-type ions because the mutual polarization affects the internuclear distance (K. Fajans[3]). Under extreme conditions, such as TlI vapor molecules, the Tl^+ ions appear to be slightly smaller than Na^+ ions.

(b) *Effect of the Electronic Configuration of Cations*

In our substitution series Table I, we have introduced only those positive cores which have

the configuration of a noble gas atom. It is not possible, for example, to estimate the acidity of $HClO_4$ and that of HIO_4 on this basis because it involves the simultaneous change of two parameters. Firstly, the I^{7+} core is larger than the Cl^{7+} core, and secondly, it has 18 outer electrons and not the octet shell. These two changes made simultaneously produce antagonistic effects. We may expect the I^{7+} core to be less polarizing than the Cl^{7+} core because of its larger size. On the other hand, we know that as a non-noble gas-type ion (Ag^+ core), the I^{7+} ion is more interpenetrable for electrons and must have a stronger polarizing effect upon its O^{2-} ions than the Cl^{7+} core. These two effects may or may not balance one another. The non-existence of the $(BrO_4)^-$ ion proves that the Br^{7+} core (Cu^+ core), in spite of its being larger than the Cl^{7+} core, not only deforms its O^{2-} ions but acts like the more powerful F^{7+} core: it pulls over electrons, liberates atomic oxygen and changes into a Br^{5+} core or, as one should describe it, it assumes the quantum configuration, $(e_2^-)\ Br^{7+}\ O_3^{2-}$. These quanticule formulae of K. Fajans[2] in which an electron pair plays the role of an O^{2-} ion explain the otherwise not understandable geometry of these groups.

The size of the Zn^{2+} ion (0.83 A.U.) ranges between that of Mg^{2+} (0.78 A.U.) and that of the Ca^{2+} ion (1.06). If the field strengths of these ions alone would determine the basicity of their hydroxides, $Zn(OH)_2$ should have acid-base properties similar to $Mg(OH)_2$ and $Ca(OH)_2$. However, the latter hydroxides do not dissolve in KOH, but $Zn(OH)_2$ forms potassium zincate. This means that zinc hydroxide is more acidic than $Mg(OH)_2$. In order to understand the influence of the electron configuration upon acidity, we derive the screening demands of these cations from the first and second ionization potentials of the elements.

Element	I. Ionization	II. Ionization	Potential I. + II.
Calcium	6.1	11.8	17.9 e.v.
Magnesium	7.6	15.0	22.6 e.v.
Zinc	9.4	17.9	27.3 e.v.

In order to remove two electrons from a zinc atom 27.3 e.v. are required, whereas 22.6 e.v. are sufficient to produce a Mg^{2+} ion from the atom and 17.9 e.v. for producing a Ca^{2+} ion. These values indicate that the screening demand of the non-noble gas-type Zn^{2+} is considerably greater than even that of the smaller noble gas-type Mg^{2+} ion.

This relation seems to hold true in a rather general way. Noble gas-like cations are better screened by their electrons than non-noble gas-like cations of the same charge and of similar size. For this reason $Mg(OH)_2$ is more basic than $Zn(OH)_2$ or $Cu(OH)_2$. $Ba(OH)_2$ is more basic than $Pb(OH)_2$.

The greater interpenetrability of non-noble gas-type ions by electrons makes an environment of polarizable anions energetically more suitable. A Cu^{2+} ion, for example, is neutralized by two $(OH)^-$ ions. In order to screen the Cu^{2+} ion, the compound $Cu(OH)_2$ has to polymerize, i.e., $(OH)^-$ ions have to be shared between two Cu^{2+} ions. The low polarizability of the $(OH)^-$ ion does not permit strong mutual deformation. Removal of the proton either through dehydration

$$Cu(OH)_2 \longrightarrow CuO + H_2O$$

or through its replacement by the weaker K^+ ion, i.e., formation of cuprites

$$Cu(OH)_2 + 2\ KOH \longrightarrow Cu(OK)_2 + 2H_2O,$$

improves the screening of the Cu^{2+} ion by greater mutual deformation (deeper color). When adsorbed on paper the $Cu(OH)_2$ receives additional screening by the OH^- groups of the cellulose and, as a result, it does not change into CuO on heating with KOH.

In F. Ephraim's Inorganic Chemistry (4th Edition) we find the following statement:

"The chemistry of the hydrated oxides of the less electropositive metals forms one of the most difficult chapters of inorganic chemistry."

Most of the difficulty is due to the lack of understanding of their acidity. Whereas noble gas-type cations, e.g., Al^{3+} and Si^{4+} ions, can be easily screened by F^- and OH^- ions, those of the non-noble gas-type, e.g., Cu^{2+}, Cr^{3+} and Ti^{4+} ions, prefer more polarizable anions and, as a result, their hydroxides are more acidic and cleave off water more readily.

The process of polymerization is complicated by the fact that cations can improve their screening by the sharing of OH^- ions as well as by changing the less polarizable OH^- ions into the more polarizable O^{2-} ions by cleaving off water.

(c) *Effect of the Valency of Elements*

In order to understand the effect of valency upon the properties of elements we shall first ask the question: What are the conditions which determine whether or not an element can form several stable quantum states, i.e., form compounds in which it occurs in several valencies? In accordance with K. Fajans[2] we describe S^{IV} and P^{III} as the positive cores of these elements plus those electrons which during chemical reactions remain quantized with respect to these cores. K. Fajans treats tetravalent sulfur or trivalent phosphorous as $S^{6+}\ (e_2^-)$ and $P^{5+}\ (e_2^-)$ respectively. This description of sulfur and phosphorus in different valence states changes the above question into: Which conditions permit the quantization of electrons or electron pairs with respect to positive cores? We see that among those cores which have the structure of the neon atom, namely,

$$Na^+,\ Mg^{2+},\ Al^{3+},\ Si^{4+},\ P^{5+},\ S^{6+},\ \text{and}\ Cl^{7+},$$

the stability of an element, El, in the quantum configuration

$$El^{x+}\ (e_2^-)$$

increases with increasing value of x. Neither $Na^+\ (e_2^-) = Na^-$ nor $Mg^{2+}\ (e_2^-) = Mg^\circ$ are stable groups at ordinary temperature. $Al^{3+}\ (e_2^-) = Al^+$ forms at high temperature (1000° C).

The divalent silicon or the $Si^{4+}\ (e_2^-)$ group has been observed in several compounds of silicon with chlorine. In combination with oxygen it is stable over a limited temperature region as silicon monoxide. Trivalent phosphorus is very common and is stable over a wide temperature region in $P^{5+}\ (e_2^-)\ Cl_3^-$ and P_2O_3, etc. When ele-

mental phosphorus is oxidized, mixtures of trivalent and pentavalent phosphorus are obtained. The same is true for elemental sulfur. Only a small fraction of this element burns to SO_3; most of it forms SO_2 or S^{6+} (e_2^-) O_2^{2-}.

As far as the Cl^{7+} core is concerned one finds Cl^{7+} (e_2^-) in the chlorate ion $(ClO_3)^-$.

From the cationic point of view, we may say that the stability of lower valence states of an element increases with increasing charge and screening demand of its core.

From the anionic point of view, treating the (e_2^-) quanticule in the same way as we treat an O^{2-} or S^{2} ion, we may say that the stability of this anion increases with the increasing positive field of the core which stabilizes it.

The quanticule (e_2^-) just like an O^{2-} ion requires a strong positive field to become stable, otherwise it dissociates:

$$(e_2^-) = e^- + e^- \quad .$$

It is this treatment of elements in different valence states which is primarily responsible for making the screening theory a useful tool. The concept of screening or shielding of atoms has been introduced into chemistry by several scientists such as J. J. van Laar, W. Kossel and, more recently, by A. E. van Arkel[4]. Especially van Arkel pointed out the weakness of the screening approach to account for geometry of CO_2 versus SO_2, etc.

It is a well established rule that elements which form different states of oxidation may form acids in the highest state of oxidation and bases in their lowest state of oxidation. Mn^{7+} is the central cation of the permanganic acid in $(Mn^{7+}\ O_4^{2-})^-$. The Mn^{2+} ion, however, is basic. The Cr^{6+} core produces the chromate ion $(Cr^{6+}\ O_4^{2-})2-$, the Cr^{3+} ion produces the amphoteric hydroxide $Cr^{3+}\ (OH)_3^-$, and the Cr^{2+} ion in CrO is basic.

This change in acidity becomes more understandable if one treats all states of oxidation as containing the cores of the elements, e.g., the Mn^{7+} or the Cr^{6+} ions. The lower oxidation numbers can be derived by replacing some of the O^{2-} ions by the better screening electrons.

For two major reasons we cannot treat an element which participates in compounds in several valencies or which has several oxidation numbers as one which forms ions which have different sizes and charges. The first major obstacle is the geometry of the compounds. The bond angle Br-Pb-Br in $PbBr_2$ vapor molecules and the O-S-O angle in the SO_2 molecule indicate clearly that we do not deal with Pb^{2+} and S^{4+} ions but with units which are better described by the Fajans' quanticule formulae:

$$\begin{matrix} e_2^- \\ Pb^{4+} \\ Br^- \quad Br^- \end{matrix} \qquad \text{and} \qquad \begin{matrix} e_2^- \\ S^{6+} \\ O^{2-} \quad O^{2-} \end{matrix}$$

The second major reason pertains to the chemistry of these compounds. Why, for example, does the hydrolysis of PCl_3 produce a dibasic acid, H_3PO_3, and not a tribasic one? The structures of P_4O_{10} and P_4O_6 will be used to introduce the quanticule formulae. Both oxides can be derived from the P_4 molecule by replacing electron pairs by O^{2-} ions.

The structure of the molecule P_4O_6 reveals four phosphorus atoms occupying the points of a tetrahedron with the six oxygen atoms just outside the middle of the six edges. The P-O distance is 1.67 A.U.

P_4O_{10} has the same structure as P_4O_6 with an extra oxygen attached to each phosphorus at a distance of only 1.39 A.U. This distance is abnormally short and, according to N. V. Sidgwick[5], no satisfactory explanation has been offered.

Replacing the quanticules e_2^- which participate in the screening of the P^{5+} cores in P_4O_6 by O^{2-} ions produces two kinds of anions, one exposed to and tightened by two P^{5+} cores and the other exposed to and deformed by only one P^{5+} core. This latter one-sided deformation causes the P-O distance to become shorter. The slightly greater acidity of H_3PO_4 as compared with H_3AsO_4 can be explained on the basis of the different sizes of the P^{5+} and the As^{5+} cores. However, the quanticule theory demands that we treat the oxides P_2O_3 and As_2O_3 as containing pairs of electrons quantized with respect to the positive cores P^{5+} and As^{5+} and having the formulae

$$P_2^{5+}\ (e_2^-)_2O_3^{2-}$$

and

$$As_2^{5+}\ (e_2^-)_2O_3^{2-}\ .$$

The As^{5+} core being of the non-noble gas-type (Cu$^+$ core) is more interpenetrable for electrons than the neon-like P^{5+} core. This explains the different reactivities of trivalent phosphorus and arsenic. The screening power of the quanticule e_2^- for a proton is greater in (e_2^-) P^{5+} than in (e_2^-) As^{5+}. It is more justifiable to call the latter an As^{3+} ion because the electrons penetrate more deeply into the As^{5+} core than they can penetrate into a P^{5+} core. This difference manifests itself in all chemical reactions, e.g., in the hydrolysis of the trihalides, as we can see from the following two equations:

$$As^{5+}\ (e_2^-)\ Cl_3^- + 3\ HOH = As^{5+}\ (e_2^-)\ (OH)_3^- + 3\ HCl$$

but

$$P^{5+}\ (e_2^-)\ Cl_3^- + 3\ HOH = H^-\ P^{5+}\ (OH)_2^-O^{2-} + 3HCl.$$

The formation of H_3PO_3, a dibasic acid which has the electronic formula

$$\begin{matrix} & H^- & \\ OH^- & P^{5+} & OH^- \\ & O^{2-} & \end{matrix}$$

from PCl_3 can be described as follows:

The protons of the H_2O molecules penetrate into the electron clouds of the Cl^- ions forming 3 HCl molecules. One proton, however, leaves the electron cloud of an O^{2-} ion and enters into the better screening e_2^- quanticule, thus forming an H^- ion. In the corresponding arsenic compound the interpenetration of the e_2^- quanticule with the non-noble gas type As^{5+} core does not favor the formation of H^- ions. It is apparent that the screening power of the quanticule e_2^- is decreased if the latter is quantized with respect to a non-noble gas-like core.

In many cases the acidity decreases if an O^{2-} ion is replaced by a better screening (e_2^-) quanticule. For example, the strong acid, perchloric acid, can be changed into the weak hypochlorous acid by replacing 3 O^{2-} ions by three electron pairs:

$$H^+ Cl^{7+} O_4^{2-} \longrightarrow H^+ Cl^{7+} (e_2^-) O_3^{2-} \longrightarrow$$
$$H^+ Cl^{7+} (e_2^-)_2 O_2^{2-} \longrightarrow H^+ Cl^{7+} (e_2^-)_3 O^{2-}.$$

The same applies to the strong sulfuric acid which is changed into the weaker sulfurous acid:

$$H_2^+ S^{6+} O_4^{2-} \longrightarrow H_2^+ S^{6+} (e_2^-) O_3^{2-}.$$

Replacing an O^{2-} ion by the larger and therefore better screening S^{2-} ion has a similar effect. Thiosulfuric acid is a weaker acid than sulfuric acid:

$$H_2^+ S^{6+} O_4^{2-} \longrightarrow H_2^+ S^{6+} S^{2-} O_3^{2-}.$$

The acidity decreases steadily from the strong $HClO_4$ to the very weak HClO. However, the next step, the replacement of the last O^{2-} ion by the quanticule e_2^- leads to HCl which is a strong acid because this step is accompanied by a requantization:

$$H^+ O^{2-} Cl^{7+} (e_2^-)_3 \xrightarrow[-O^{2-}]{+e_2^-} H^+ Cl^{7+} (e_2^-)_4 \longrightarrow H^+ Cl^-.$$

With an increasing number of O^{2-} ions being replaced by the better screening (e_2^-) quanticule, the screening of the Cl^{7+} core improves. The screening of the Cl^{7+} core affects the screening of the proton because the improving of the screening of the Cl^{7+} core decreases its deforming influence upon the O^{2-} ion. The less the O^{2-} ion is polarized by the Cl^{7+} the better it can screen the proton and the less acid becomes the molecule. This influence can be observed when going from $HClO_4$ to HClO, but the replacement of the last O^{2-} ion by two electrons forces the proton to enter the electron cloud of the Cl^- ion where it is repelled by the Cl^{7+} core.

(d) Salt Formation

In our scheme (Table I) phosphoric acid was obtained by replacing five protons of the water by one P^{5+} ion. This substitution which has changed the neutral water into an acid can be counteracted by a substitution which, by itself, would change the water into a base, e.g., replacing additional protons by K^+ ions. Both substitutions work in opposite directions. The acidity of the system depends upon the number of cations which we substitute for protons and upon their electrical fields. For this reason it could only be a coincidence if neutrality would be restored if the P^{5+} and K^+ ions were present in a stoichiometric ratio, e.g.,

H_{2n-5}^+		P^{5+}	O_n^{2-}	Solution of H_3PO_4
H_{2n-6}^+	K^+	P^{5+}	O_n^{2-}	Solution of KH_2PO_4
H_{2n-7}^+	K_2^+	P^{5+}	O_n^{2-}	Solution of K_2HPO_4
H_{2n-8}^+	K_3^+	P^{5+}	O_n^{2-}	Solution of K_3PO_4

Our scheme eliminates the difficulty which arises from the fact that $KHSO_4$ is acidic but Na_2HPO_4 is basic.

Our scheme explains why an "acid salt" can be basic, e.g., K_2HPO_4 or $KHCO_3$, and why the addition of an apparently neutral salt, e.g., NaCl, affects the acidity of an aqueous solution of HCl. The acidity of a solution is not located in one constituent but it is given by the degree of screening of all its cations.

In our scheme (Table I) we have changed the neutral substance water into a base by replacing some hydrogen ions by an equivalent amount of cations which have a weak field, e.g., K^+ or Ba^{2+} ions. We have changed water into an acid by replacing protons by an equivalent number of cations which had a very strong field, e.g., S^{6+} and Cl^{7+} cores. Can this principle also be used in order to increase the acidity of a typical base such as ammonia? According to our concept of ammonia as a nitride ion which screens three protons, we explain its basicity by the fact that this molecule can easily screen an additional proton and form the complex cation NH_4^+. The problem of making an acid out of ammonia can be formulated as follows: Which positive cores can be substituted for two of the three protons of NH_3 so that the screening demand of the third proton becomes sufficiently large that it penetrates an O^{2-} ion of water? As far as the field strength of positive cores is concerned, the C^{4+} core ranks very high.

Indeed, the basicity of NH_3 can be decreased considerably by replacing two of the protons by two C^{4+} cores, especially if the latter are poorly screened, i.e., if their residual charges are neutralized by F^- ions. The compound $(CF_3)_2$ NH has lost its basic properties with respect to H_2O but still it is not an acid.

In order to make the NH-group an acid we have to expose it to a core which is not only highly charged but also interpenetrable for electrons. The Os^{8+} core can impair the screening of the proton to such an extent that it becomes acidic. Replacing an O^{2-} ion of OsO_4 by the $(NH)^{2-}$ group produces a fairly strong acid, the osmiamic acid, $Os^{8+} O_3^{2-} (NH)^{2-}$. This compound is not hydrolyzed even by strong KOH because of the interaction of the highly polarizable N^{3-} ion and the highly interpenetrable Os^{8+} core.

(e) Polymerization

Acid molecules can improve the screening of their positive cores by sharing anions, e.g.,

$$SO_3 = \ldots \begin{matrix} O & O & O & O \\ O & S & O & S & O & S & O & S & O \\ O & & O & & O & & O & & O \end{matrix} \ldots$$

The SO_3 molecules polymerize and form a solid because the expansion of the coordination number of the S^{6+} core from three to four provides better screening. If such a process takes place in aqueous solution it leads to isopoly acids, e.g., polysilicic acid. The polymerization of chromic acid leads first to dichromic acid:

$$\begin{matrix} & & O^{2-} & & O^{2-} & & \\ (OH)^- & Cr^{6+} & O^{2-} & Cr^{6+} & O^{2-} & (OH)^- \\ & & O^{2-} & & O^{2-} & & \end{matrix}$$

This process can continue and produce chain-like anions, for example, the trichromate $(Cr_3O_{10})^{2-}$ ion:

$$\begin{matrix} & & O^{2-} & & O^{2-} & & O^{2-} & \\ O^{2-} & Cr^{6+} & O^{2-} & Cr^{6+} & O^{2-} & Cr^{6+} & O^{2-} \\ & & O^{2-} & & O^{2-} & & O^{2-} & \end{matrix}$$

Both processes, the expansion of the coordination by sharing anions and the formation of oxygen bridges, may take place simultaneously. In this case the reaction product has a structure which depends upon the environment and on the temperature. Usually its structure changes with time because the two processes are likely

(*Continued on page* 286)

Inventions and Inventors

Annealing and Tempering

Glass Bending Fixture. Fig. 1. Patent No. 2,720,729. Filed October 3, 1952. Issued October 18, 1955. One sheet of drawings. Assigned Ford Motor Co., by O. E. Rugg.

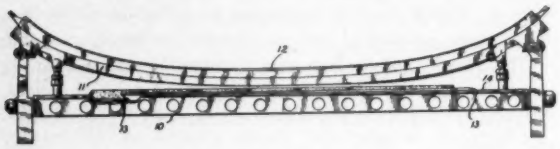

Fig. 1.

This invention deals with the art of bending glass and more particularly with an improvement in an apparatus used for bending laminated glass windshields.

The fixtures usually employed for this purpose support the glass only around the edges and leave it unsupported at those portions remote from the edges. Difficulty has been encountered with the center portions of the glass sagging to a greater extent than the edges with the concomitant production of optically deflective glass.

Figure 1 shows a glass bending fixture generally denominated as 10, in which a pair of glass sheets 12 are supported upon a bending surface 11. To avoid undesirable excessive sag, a layer of porous brick or other refractory material is placed in the fixture and supported by a perforated sheet 13, which is welded to bar 14 and which extends along the length of fixture 10.

While the exact operation of this fire brick to prevent the sag is not known, it is thought that in the earlier stages of heating the fire brick preferentially absorbs heat, which would otherwise be reflected from the lower portion of the bending lehr to the glass.

There were 3 claims and the following reference cited in this patent: 2,348,278, Boyles et al., May 9, 1944.

Decorating Glassware. Patent No. 2,721,535. Filed November 9, 1953. Issued October 25, 1955. Two sheets of drawings; none reproduced. Assigned to Owens-Illinois Glass Company by V. J. Zitkus.

The present invention relates to apparatus for decorating articles of glassware, such as tumblers and the like. It is common practice to spray frost, or similarly apply an overall decorative coating to the exterior surface of tumblers. The overall coating and particularly the customary white frosting is objectionable, especially at the rim or lip of the tumbler, as it frequently becomes discolored with lipstick, etc., which is difficult to remove, as compared with the ease of removal from clear glass.

In order to restrict the application of the coating material to a surface spaced from the upper end of the tumbler and define a sharp clear upper margin for such coating, an annular sheet of air is directed under pressure, inwardly and slightly downward, against the outer surface of the glass at the desired level. This sheet of air provides an effective barrier to the passage of the coating material above the desired point. Thus, the tumbler has a clear uncoated area at and in proximity to the rim portion.

The air pressure is exceedingly important. If the pressure is too low, there is a strong tendency for the upper margin of the applied coating to be irregular and feathered. On the other hand, too high a pressure results in a heavy layer at said margin. A pressure of approximately five to six p.s.i. produces very satisfactory results. There were ten claims and the following references cited in this patent: 1,226,856, Bradley, May 22, 1917; 1,347,994, Day, July 27, 1920; 2,084,094, Kronguest et al., June 15, 1937, and 2,088,542, Westin, July 27, 1937.

Feeding and Forming

Mold Mechanisms Glass Machines. Patent No. 2,722,084. Filed August 5, 1946 and November 19, 1951. Issued November 1, 1955. Four sheets of drawings; none reproduced. Assigned to H. C. Daubenspeck, by Samuel E. Winder.

The present invention relates generally to mold mechanisms for a bottle forming machine.

In use, it is necessary to have certain parts of the machine capable of change. For example, molds must be changeable to make ware of different shapes and sizes.

The mold sets, both blank and blow molds, may be withdrawn as units. The screws that hold the blocks to the table are removed and the air connections released, whereupon any blank mold may be withdrawn as a unit including its power cylinder and valve. Any blow mold unit may likewise be withdrawn. As the blocks are all identical, this makes possible the quick removal of any old mold and the substitution of another one. The several blank mold units are all interchangeable, as are the blow mold units. In replacing one unit with another, complete and accurate alignment is obtained by the engagement of the mold pin in a hole and the saddling of a block in a yoke or a notch. Thereafter, these screws are tightened merely as holding means. No drive pins or the like are required. These positioning elements are sufficiently removed from the highly heated parts to be unaffected by expansion.

A blank mold may be removed from its pin by disconnection of the links and the lifting of the mold sections from the pin. Thereafter, a different mold may be installed over the pin and properly connected to the yoke. Conventionally, all molds have hinge ears of the same size and shape. The changing of a blow mold follows like procedure, thus provides for faster production of better ware, with little complication. There were 8 claims and 17 references cited.

Forming Apertures In Glassware. Patent No. 2,722,086. Filed August 8, 1952. Issued November 1, 1955. One sheet of drawings; none reproduced. Melvin Z. Mullen.

A simple, rapid and effective method is provided for forming a tubular connecting wall in bottles, flasks and the like. The method embodies spot heating each side

wall over a restricted alined area, to a point of flux, while exhausting the pressure within the hollow article. The fused glass from both side walls is allowed to unite, due to external pressure and form a continuous transverse tubular connecting wall between. Before complete cooling, a mandrel of selected cross sectional configuration is inserted through the tubular connecting wall to provide the finished aperture.

Such apertures may be used for artistic design of utilitarian purposes to transmit chemicals and other fluids through hollow stoppers from a fluid supply line.

There were 7 claims and the following references were cited in this patent: D. 34,895, McFaddin, Aug. 6, 1901; D. 47,650, Roach, July 27, 1915; 1,301,714, Keuppers, Apr. 22, 1919; 1,967,603, Zimber, July 24, 1934; 2,491,848, Breadner et al., Dec. 20, 1949; 15,114, Great Britain, Aug. 29, 1907, and 718,140, France, Jan. 19, 1932.

Glass Blowing Machine. Patent No. 2,729,916. Filed March 17, 1951. Issued Jan. 10, 1956. 3 sheets drawings; none reproduced. Assigned to General Electric Co., by A. F. Caster and J. H. Carlstrom.

The invention relates to machines for blowing glass articles and more particularly, to glass blowing machines which form blown articles from plastic glass while carrying the glass along an extended horizontal path.

One particular species of machine to which the invention relates is exemplified by the glass blowing machine shown in Patent 1,790,397, W. J. Woods, et al., dated January 27, 1931.

A salient feature of the invention is the mounting of a plurality of blow-heads and mold carriers in groups on respective individual links of respective articulate carriers. The blow-heads and mold carriers are arranged in groups of two on the respective links. The advantages of the apparatus are presented by novel combined mold operating and rotating means and have a readily separable coupling arrangements for attaching the molds. The several improvements adapt the apparatus to speeds of operation much greater than ever possible and enable more satisfactory operation of the blowing machine and also more rapid repair.

There were 4 claims and 14 references cited.

Glass Compositions

Ultraviolet Discharge Lamp. Patent No. 2,719,932. Filed March 14, 1949. Issued October 4, 1955. One sheet of drawings; none reproduced. Assigned to General Electric Company, by J. E. Stanworth.

The invention relates to gaseous electric discharge lamps and more particularly to such lamps emitting ultraviolet radiations of 2537 A. wave length.

The glass composition preferably falls within the following range of composition by weight, viz., $SiO_2+B_2O_3$ 60—74 per cent; B_2O_3 up to 5 per cent; $Na_2+K_2O+Li_2O$ 13—20 per cent; BaA+MgO+CaO 8—27 per cent. A composition found particularly useful is one comprising SiO_2 65 per cent; B_2O_3 2 per cent; Na_2O 5.5 per cent; K_2O 9.5 per cent and BaO 18 per cent. In a glass of this composition the amount of aluminum to be used is about 0.03 per cent of the weight of the finished glass. This percentage may be varied somewhat according to (a) the grain size of the raw materials, particularly that of the sand, and (b) the conditions of melting, for example whether the batch is melted under slightly oxidizing conditions or slightly reducing conditions. If melted under slightly oxidizing conditions a slightly higher percentage of aluminum is required. The function of the aluminum is primarily to insure that such iron oxide as is present in the final glass is in the ferrous form.

The glass melts readily in the flame, is not subject to devitrification during manufacture and use, will make satisfactory seals to metals, such as copper-coated nickel-iron, usually employed for lead-in conductors in incandescent and fluorescent lamps, and may be hermetically united with the lead glass stems now used for such lamps.

There were ten claims and the following references cited in this patent: 2,001,504, Schmidt, May 14, 1935; 2,010,836, Adams, Aug. 13, 1935; 2,056,930, Navias, Oct. 6, 1936; 2,445,012, Van Orden, July 13, 1948, and 2,379,164, Inman, Aug. 16, 1949.

Glass and Wool Fiber

Forming Mat of Glass Fibers. Patent No. 2,723,209. Filed September 18, 1951. Issued November 8, 1955. No drawings. Assigned Owens-Corning Fiberglas Corp. by T. E. Philipps.

This invention relates to a thin, porous sheet or mat of glass fibers having the properties of high tensile and tear strength, resiliency, good flexibility and resistance to moisure, to high and low temperatures, to the attack of elements ordinarily found in the ground or in the air and to the destruction of the glass fibers during application or in position of use.

A small amount of the resinous binder is sprayed onto the glass fibers, while in the collecting chamber. The binder operates to impart increased mass integrity, to enable the subsequent handling of the thin mat of interlaced fibers. The mat is then led over rollers, into an impregnating area, where the mat is fully wetted with the treating material. The impregnation may be effected by submersion of the mat in a dip tank, by means of a flow coat process, while the mat is passing over or between rolls, or some other suitable impregnation means such as spraying. The excess binder which drips from the impregnated mat may be collected in a trough and returned to the supply reservoir and, subsequently, a pair of wiping rolls may smooth out the resinous application and remove further excess of binder from the mat.

The baking ovens are maintained at temperatures in the range of 250-450°F. and as the impregnated mat passes through, the binder is converted to its cured stage.

The binder is formulated as follows:

12 pounds Hycar OR25 latex, 40 percent solids.

3 pounds phenolic resin (Catavar 156), 60 per cent solids.

4 grams sulphur.

27.5 grams Phenex (a phenol derivative accelerator)

31.5 grams Methocel (methyl cellulose)

The resulting mat develops adequate strength with a minimum of resinous binder because the major part of the resinous material has ample time due to its slow

rate of cure to migrate along the lengths of fiber and gather in higher concentrations at junctures of the fibers where it operates more effectively and efficiently to bind the fiber together in the mat.

There were 8 claims and the following references cited in this patent: 2,298,295, Hyatt et al., Oct. 13, 1942; 2,349,909, Meharg, May 30, 1944; 2,459,739, Groten et al. (2) Jan. 18, 1949; 2,504,845, Keyes, Apr. 18, 1950; 2,523,759, Grant, Sept. 26, 1950; 2,550,465, Gorski, Apr. 24, 1951, and 2,581,926, Groten et al., Jan. 8, 1952.

Rollers For Feeding A Continuous Strand. Patent No. 2,715,299. Filed. August 14, 1952. Issued August 16, 1955. One sheet of drawings; none reproduced. Assigned to Owens-Corning Fiberglas Corporation by William R. Steitz.

This invention relates to the art of feeding continuous strands of material and in particular to improvements in high speed coacting pulling rollers, which are driven to produce linear speeds of their peripheries for example, as high as 10,000 feet per minute.

By firmly grasping the strand between the pulling roller surfaces, better control over and uniformity in its rate of feeding result. By initiating a wave pattern of fixed dimensions, a better control over the general wave form pattern in which the strand falls is experienced. Individually replaceable lugs improve the strand handling characteristics of pulling rollers as well as simplify the replacement of worn parts and reduce the weight of the pulling rollers by eliminating structural members designed to retain the strand contacting portions of the rims in place on the rollers.

There are 5 claims and 6 references cited in this patent. 2,161,502, Brown, June 6, 1939; 2,223,914, Karns. Dec. 3, 1940; 2,259,202, Cooper, Oct. 14, 1941; 2,348,182, Slayter, May 2, 1944; 2,434,964, Rarick, Jan. 27, 1948 and 2,435,891, Lodge, Feb. 10, 1948.

Asphalt Emulsion and a Process of Coating a Glass Fiber Mat With It. Patent No. 2,712,506. Filed May 24, 1951. Issued July 5, 1955. No drawings. Assigned to Owens-Corning Fiberglas Corporation, by Robert W. Farris.

This invention relates to asphaltic emulsions and more particularly to asphaltic emulsions for use in combination with glass fibers in the manufacture of bonded mat. It is desirable to make use of an emulsion which in combination with a glass fiber fabric is able to set rapidly into a highly flexible, tack-free product to permit handling almost immediately after treatment. It has been found that the viscosity of an emulsion may be greatly lowered, that the penetrability of the glass fiber mat or fabric may be greatly increased and the asphaltic component quickly set into a highly flexible, tack-free product having good weathering and oxidation resistance, when the emulsion is formulated with a small amount of an anionic compound in the form of a hydrophilic salt of di (2-ethyl hexyl) phosphoric acid. Such salts as sodium di(2-ethyl hexyl) phosphate potassium di(2-thyl hexyl) phosphate, lithium di(2-ethyl hexyl) phosphate, ammonium di(2-ethyl hexyl) phosphate and the like, have been quite encouraging. The amount of anionic compound effective for achieving the desired results in the asphaltic emulsion ranges from 0.005 to 1.0 percent by weight based on the amount of asphaltic emulsion. Since the additive is soluble in substantially all proportions in water, it is convenient to prepare a stock solution of the water soluble salt of di(2-ethyl hexyl) phosphoric acid and incorporate the desired amount of the solution in the asphaltic emulsion with or without further dilution with water. Application of the asphaltic emulsion in the manufacture of bonded mat of glass fibers may be achieved by way of a flow-coating process in which a constant stream of the emulsion is poured over the glass fiber mat after it is formed. Ordinary treatment to deposit about 40 per cent by weight asphalt in the bonded mat is sufficient, but the amount of asphalt may vary from 20-50 percent by weight. After application of the emulsion to the mat of glass fibers, rapid set to conditions for handling is achieved by heat treatment at temperatures ranging from 250° to 850° F. upon exposure of 2-10 minutes.

The patent contains eight claims and the following references were cited: 2,408,232, Smith, Sept. 24, 1946 2,503,246, Craig, Apr. 11, 1950, and 2,568,849, Fasolo, Sept. 25, 1951, and 779,503, France, Apr. 8, 1935.

Pipe from Glass Fiber and Plastic Material. Patent No. 2,714,414. Filed August 17, 1950. Issued August 2, 1955. Two sheets of drawings; none reproduced. Assigned to Owens-Corning Fiberglas Corp., by Carl D. Ganahl, John A. Grant, and C. E. Bacon.

The invention relates to the fabrication of pipe from glass fiber strands or yarns and plastic material.

A mandrel of metal such as steel, for example, with a highly polished and preferably chromium-plated outer surface, is fed upwardly by suitable driving rolls. A succession of such mandrels is thus advanced upwardly in a continuous manner. At a suitable point, as the mandrel advanced upwardly, a plurality of strands of glass fibers are withdrawn from spools or boxes carrying such material. They are then dipped momentarily in a plastic material in liquid form and immediately wound helically upon the mandrel at an angle to the axis. The preferred angle is 63.45°, which is adapted to give the pipe twice the strength circumferentially than it has lengthwise.

It is preferable to employ thermosetting resins of the polymerization type, which are readily converted, from a monomeric stage by the action of a low degree of heat and little or no pressure. Such resins known as contact resins may be readily applied to the strand in a liquid monomeric form or as a partially polymerized solvent solution. These resins may consist of polymers and copolymers from such groups as allyl compounds and their derivatives, polyester resins, styrene derivatives or acrylic acid and ester derivatives.

The material on the mandrel is then severed from that on the succeeding mandrel manually or otherwise, so that the uppermost mandrel with the material wound thereon, can be removed and deposited in a suitable chamber or oven where the temperature is raised to about 230° F.

The pipe is relatively light compared with pipe made from iron or steel, copper or the like. It is nevertheless strong and sufficiently rigid, with considerable elasticity.

There are 17 claims and 11 references cited in this patent. 1,110,671, Cobb, Sept. 15, 1914; 1,674,171, Gam-

meter et al., June 19, 1928; 1,708,129, Gammeter, Apr. 9, 1929; 2,352,533, Goldman, June 27, 1944; 2,402,038, Goldman et al., June 11, 1946; 2,442,948, Bogoslowsky, June 8, 1948; 2,467,999, Stephens, Apr. 19, 1949; 2,489,503, Sampson et al., Nov. 29, 1949; 2,509,715, Allen et al., May 30, 1950; 2,571,717, Howald et al., Oct. 16, 1951, and 2,629,894, Boggs, Mar. 3, 1953.

Sheet and Plate Glass

Electrically Heating and Welding Glass Elements. Patent No. 2,719,386. Filed April 30, 1952. Issued October 4, 1955. No drawings. Assigned to Pittsburgh Plate Glass Company, by Ralph A. Johnson and Reverdy E. Baldwin.

The invention relates to an electrically conductive solution of colloidal graphite, suitable for use in the production of all glass welded double glazed units.

The electrically conductive solution comprises an aqueous solution of colloidal graphite and an alkali metal carboxyalkyl cellulose such as lithium, potassium or sodium carboxymethyl cellulose. The use of such an electrically conductive solution has resulted in production of more uniform stripes whose preheating, electrical resistance and welding qualities are excellent and easily reproducible.

Various techniques may be employed to apply the electrically conducting stripes to the glass. For example, the stripes may be applied by painting, brushing, spraying or screening.

After the margins of at least one of the glass sheets have been striped as desired with the electricity conducting solution of colloidal graphite and sodium carboxymethyl cellulose, the two sheets of glass to be welded are placed in a preheating furnace which brings the glass up to a temperature of approximately 1000 to 1100°F. preparatory to welding. During this preheating, virtually all of the sodium carboxymethyl cellulose and any other organic constituent burn out leaving a graphite strip whose electrical characteristics approach those of a metallic ribbon of greatly reduced resistance.

The current is applied to the stripes by means of suitable electrodes positioned at each corner of the glass sheet. Starting with an initial temperature of 1100°F., the temperature of the glass is gradually and substantially uniformly raised to about 1900 to 2000°F. This increase in temperature reaches a maximum in the area of the stripes of collodial graphite, and is progressively lower towards the center of the sheets of glass. This maximum temperature is reached only after the stripes of graphite have been burned off and portions of the marginal edges of the upper sheet have softened and sagged down to engage the marginal edges of the lower sheet of glass.

There were 14 claims and the following references cited in this patent. 2,176,879, Bartell, Oct. 24, 1939; 2,389,360, Guyer et al., Nov. 20, 1945; 2,394,051, Guyer et al., Feb. 5, 1946; 2,445,374, Van Wyck, July 20, 1948; 2,570,827, Madison, et al., Oct. 9, 1951; 665,474, Germany, Sept. 26, 1938, and *Hercules*, "Sodium Carboxymethyl Cellulose," 1944, page 4.

Tube and Cane Machines

Lamp Sealing Apparatus. Patent No. 2,721,422. Filed January 30, 1953. Issued October 25, 1955. Six sheets of drawings; none reproduced. Assigned to Sylvania Electric Products, Inc., by H. E. Baker and J. H. Brooks.

This invention relates to the manufacture of fluorescent lamps. Lamp mounts are sealed to the ends of an elongated lamp tube, on a continuous motion conveyor, with the lamp mounts and the lamp tube rotating about their own axis. The lamp mounts are supported by heads which comprise a pair of spindles. The lamp tubes are supported by cradles all of which are in alignment so as to move in proper engagement. The apparatus affords the advantage of sealing the ends of the lamp tubes simultaneously, instead of sequentially, and at the same time all sealing is done with the lamp tube in a horizontal position and not vertical. It is claimed that greater speeds are possible with the apparatus.

There were 12 claims and the following references cited in this patent: 2,434,664, Malloy, Jan. 20, 1948; 2,455,317, Schneider, Nov. 30, 1948; 2,575,746, Cartun, Nov. 30, 1951; 542,173, Germany, Jan. 22, 1932; 641,235, Great Britain, Aug. 9, 1950, and 168,450, Austria, June 11, 1951.

Electroconductive Article. Fig. 2. Patent No. 2,710,900. Filed October 13, 1950. Issued June 14, 1955. One sheet of drawings. Assigned to Pittsburgh Plate Glass Company, by Cyril S. Linder.

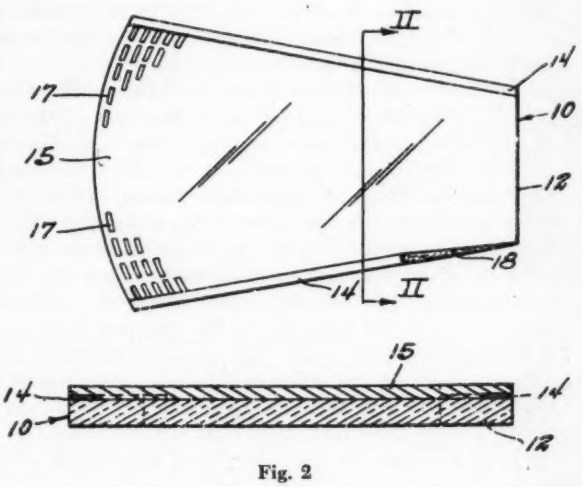

Fig. 2

This invention relates to improve windshields or other similar structures, having electroconductive transparent coatings deposited thereon.

In Fig. 5 the heating panel 10 comprises an irregularly shaped glass sheet 12 having bus bars or conductive marginal edge strips 14 or an electroconductive metal such as gold, silver, copper, etc. along opposite edges and close to the edges (preferably within 0.5 inch of the edge or on the edge) of the sheet. These bus bars are disposed along the longest pair of opposite sides of the panel whereby the distance between the bus bars is held to a minimum. The bus bars 14 may be connected to opposite poles of a source of potential (not shown).

The panel 10 is provided with an electroconductive transparent film 15 such as may be produced by spray-

(*Continued on page 282*)

Effects of Various Mineralizing Agents in Promoting Recrystallization in Mixtures of Clay and Alumina During Firing

[*Editor's Note:* The life of a glass furnace depends greatly upon the refractory materials used in its construction. For years the glass manufacturer has felt that the development of improved refractory materials has lagged behind his demands. It is, therefore, interesting to note the following paper by Moore and Prasad, *Journal of the Society of Glass Technology*, October 1955, which gives the results of an investigation, aimed at improving the refractory end product.]

The breakdown of the clay mineral when clay or mixtures of clay with alumina are fired at high temperatures, followed by regrouping of the silica and alumina, gives rise to mixtures consisting mainly of mullite in a vitreous matrix, with some cristobalite if the silica content is high, or with some corundum if the alumina content is high. Other crystals, either silicates or double silicates, may be present in small amounts, in some instances, depending on the nature and amounts of any non-aluminous, non-siliceous constituents which may have been present as impurities in the raw materials, or which may have been added intentionally to the original mixture.

The rate at which recombination of the constituents occurs during firing is determined by the form and state of subdivision of the raw materials, by the temperature of firing and by the amounts and nature of the non-siliceous, non-aluminous constituents present. These latter, whether present as impurities or as intentional additions, are commonly referred to as *mineralizers*. The presence of small amounts of these mineralizers may be advantageous, since they enable recrystallization to occur and a close-textured refractory to be produced, by firing at temperatures much lower than would be necessary in their absence. On the other hand, since these mineralizers are largely or entirely incorporated into the vitreous matrix during the firing, they must not be present in too large amounts, nor must they be of types which will render the vitreous matrix too readily fusible.

Quantitive information concerning the relative activities of different mineralizing agents in promoting recrystallization in alumina-silicate mixtures was not readily available and it was the object of this investigation to obtain such information. The effects of various mineralizing agents in promoting the mullite formation in mixtures of china clay and alumina was, therefore, investigated by determining the amounts of mullite, corundum and glass in specimen which had been fired at temperatures of 2372° F. and 2912° F. for periods of 24 hours. A specially pure china clay was used and the alumina was added as calcined alumina in proportions, so as to give overall compositions corresponding with mullite, $3Al_2O_3 \cdot 2SiO_2$, and with sillimanite, $Al_2O_3 \cdot SiO_2$. The mullite and corundum contents of the fired specimen were determined by adding a known proportion of fluorite to the powdered specimen and then obtaining the X-ray diffraction pattern of the mixture. The relative proportions of mullite and fluorite and of corundum and fluorite were then determined by comparing the photographic densities of lines characteristic of these three types of crystal in the X-ray-diffraction patterns obtained.

The mineralizing agents investigated included six sodium salts, the fluorides and carbonates of lithium, potassium, magnesium and calcium, and also titania, manganese dioxide and ferric oxide.

From the results obtained the following conclusions were drawn: With all the mineralizing agents, except ferric oxide, the additions which have maximum mullite formation were equivalent to 1 per cent or less of the corresponding oxides, if the mixtures were to be fired at 2552° F., and smaller amounts were needed at 2732° F. or 2912° F.

Increases in the amounts of the various mineralizers beyond these proportions cause mullite breakdown and yield corundum and glass. The amounts of the different mineralizers which can be tolerated without reducing the amounts of mullite to values significantly lower than would be given by the original mixtures, without additions, are shown in Table I, page 279. The values shown in brackets in this table are estimated from the trends in the mullite values in cases where the increases in the amounts of mineralizing agents in the various series of mixtures were comparatively large.

The permissible ranges given in the table are larger when the mixtures are fired at 2552° F. than when firing is carried out at higher temperatures. If, however, refractory mixtures with the maximum permissible amounts of the various mineralizers were to be used at temperatures in excess of those given, mullite breakdown would be correspondingly increased. Mullite breakdown would, of course, be increased inevitably during the use of the refractories for glass melting, due to the action of alkali, lime or boric oxide in the molten glass. To ensure good resistance to mullite-breakdown and consequent good resistance to solution or wear of refractories, therefore, the amount of added mineralizers should be kept well below the maximum permissible amounts and as near to the optimum amounts as possible.

The apparent porosity values of the mullite specimens containing even the maximum permissible amounts of the various mineralizers were, as a rule, considerably higher than would be acceptable commercially in refractories to be used for glass melting. The apparent porosities of the corresponding sillimanite specimens were considerably lower than those of the millite specimens, and in some cases, might be regarded as lying within the commercially acceptable range. No agreed definition of the range of commercially acceptable values of apparent porosity has ever been drawn up, as far as has been ascertained, but a true porosity in the region of 20 per cent may be regarded as desirable, consequently an apparent porosity greater than 20 per cent would be too

(*Continued on page* 279)

Current Statistical Position of Glass

Employment and payrolls: Employment in the glass industry during February, 1956 was as follows: *Flat Glass:* A preliminary figure of 29,200 for February, 1956 indicates a decrease of 3.6 per cent from the adjusted 30,300 reported for January, 1956. *Glass and Glassware, Pressed and Blown:* No change is shown by the preliminary 78,300 figure of February, 1956 when compared with the 78,300 figure of January, 1956. *Glass Products Made of Purchased Glass:* The preliminary February 1956 figure of 15,900 indicates a drop of 1.2 per cent from the previous month's 16,100 figure. Payrolls in the glass industry during February, 1956 were as follows: *Flat Glass:* A decrease of 10.7 per cent is shown in the preliminary $14,109,732.00 when compared with January, 1956 adjusted $15,802,056.00. *Glass and Glassware, Pressed and Blown:* An increase of 1.5 per cent is shown in the preliminary $26,383,968.00 reported for February, 1956 when compared with the previous month's adjusted $26,004,213.00. *Glass Products Made of Purchased Glass:* A preliminary figure of $4,615,611.00 was reported for February, 1956. This is 2.8 per cent lower than the adjusted January, 1956 figure of $4,748,373.00.

GLASS CONTAINER SHIPMENTS

(All Figures in Gross)

Narrow Neck Containers

	March, 1956
Foods	1,025,000
Medicinal and Health Supplies	1,432,000
Chemical, Household and Industrial	839,000
Toiletries and Cosmetics	831,000
Beverage, Returnable	1,547,000
Beverage, Non-returnable	109,000
Beer, Returnable	273,000
Beer, Non-returnable	667,000
Liquor	877,000
Wine	470,000
Sub-total (Narrow)	8,070,000

Wide Mouth Containers

Food	*2,719,000
Medicinal and Health Supplies	415,000
Chemical, Household and Industrial	171,000
Toiletries and Cosmetics	254,000
Packers' Tumblers	124,000
Dairy Products	203,000
Sub-total (Wide)	3,886,000
Total Domestic	11,956,000
Export Shipments	214,000
TOTAL SHIPMENTS	12,170,000

* This figure includes Fruit Jars and Jelly Glasses.

GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures in Gross)

		Production March 1956	Stocks March 1956
Foods: Medicinal and Health Supplies; Chemicals, Household and Industrial: Toiletries and Cosmetics	Narrow Neck	4,150,000	4,870,000
	Wide Mouth	*3,798,000	*4,933,000
Beverage, Returnable		1,164,000	1,234,000
Beverage, Non-returnable		101,000	191,000
Beer, Returnable		340,000	431,000
Beer, Non-returnable		622,000	848,000
Liquor		916,000	1,016,000
Wine		430,000	478,000
Packers' Tumblers		129,000	165,000
Dairy Products		215,000	350,000
TOTAL		11,865,000	14,516,000

* This figure includes Fruit Jars and Jelly Glasses.

Glass container production based on figures released by the Bureau of Census rose 6.6 per cent during March, 1956 to reach 11,865,000 gross. This is an increase from the previous month's 11,128,000 gross. During March, 1955 production was 11,293,000 gross, or 4.8 per cent lower than the March, 1956 production. Glass container production for the first three months of 1956 has reached a preliminary total of 34,092,000 gross.

Shipments of glass containers during March, 1956 increased 19.8 per cent to reach 12,170,000 gross. This is an increase over the February, 1956 shipments which were 10,172,000 gross. Shipments during March, 1955 were 11,130,000 gross, or 8½ per cent lower than March, 1956. The preliminary total shipments for 1956 is 32,156,000 gross which is 6.2 per cent ahead of the 30,173,000 gross shipped during the corresponding period in 1955.

Stocks on hand at the end of March, 1956 were 14,516,000 gross. This is 2.5 per cent lower than the stocks of 14,882,000 gross on hand at the end of February, 1956 and 1.8 per cent higher than the 14,247,000 gross on hand at the end of March, 1955.

Automatic tumbler production during February, 1956 was 5,316,251 dozens. This is an increase of 1.2 per cent from February, 1955 production which was 5,253,867 dozens. Production during the year 1956 was 10,648,757 dozens. Shipments during February, 1956 dropped to 4,641,469 dozens. This is 1.7 per cent lower than the February, 1955 figure of 4,721,291 dozens. During the year 1956 shipments were 9,127,235 dozens. At the end of the 12-month period ending February 29, 1956, shipments rose to reach a total of 62,048,973 dozens, which is only 1.1 per cent lower than the 62,753,437 dozens shipped in the similar period last year.

Table, kitchen and household glassware: Manufacturers' sales of machine-made table, kitchen and household glassware during February, 1956 rose 3.2 per cent to reach 3,188,001 dozens. This is an increase from the February, 1955 figure of 3,089,401 dozens. During the year 1956, sales were 5,719,215 dozens. At the end of the 12-month period ending February 29, 1956 manufacturers had sold a total of 37,239,051 dozens, which is 1.8 per cent below the 37,889,203 dozens sold during the corresponding 1955 period.

(*Continued on page* 294)

New Equipment and Supplies

TELESCOPING PORTABLE LIFT

The Oster Manufacturing Company, Box 4326, Cleveland 32, Ohio, has introduced a 112 inches telescoping portable lift which provides mechanized raising and lowering of loads with non-powered horizontal transportation.

The telescoping lift has been designed for high stacking operations. It has, however, a collapsed height, low enough for handling loads in elevators, under balconies and in other low head room areas.

The new model, number L1112-P, has a 1000 pound capacity and a battery-powered hydraulic lift. It can be used as a platform truck, a straddle fork truck, a portable elevator, or a shop crane. This versatile lift can be operated by one man.

Lift height-minimum 2 inches to maximum 112 inches. Additional information may be obtained direct from the company.

WET DUST COLLECTOR

Pangborn Corporation, Hagerstown, Maryland, announces the "Ventrijet" wet dust collector. The Ventrijet achieves the proper atomizing of water and mixing with the air stream to permit efficient dust transfer by the movement of air, without mechanical means.

Dust laden air enters the collector and expands in the inlet chamber at reduced velocity. The heavier particles sink to the bottom of the tank as sludge. The air is drawn through one or more venturi tubes into the discharge chamber. The low pressure area in the venturi throat induces water to enter the high velocity air stream. The mixing of air and water causes the transfer of dust particles from the air to the water particles. The air, water and sludge mixture impinges at high velocity on special surfaces in the discharge chamber. The sludge settles to the tank bottom. The washed air then flows through an eliminator section for removal of droplets and only purified air is discharged.

DOUBLE-HEAD EIGHT FOOT SWING ARM POLISHER

Sommer and Maca Glass Machinery Company, 3600 South Oakley Avenue, Chicago 9, Ill. offers a new double-head arm polisher. The machine presents double polishing facilities in one unit with eight foot working radius for repolishing (blocking) plate glass.

It is equipped with two 8 inches diameter flexible type felt blocks, mounted on a swing arm of sturdy box frame, all-steel construction. Power is transmitted from the motor to the spindles with four endless V belts. For complete specifications write the company direct.

BATCHING SCALE HANDLES FLOODING TYPE CHEMICALS AND PULVERIZED PRODUCTS

The Thayer Scale and Engineering Corporation, Rockland, Massachusetts, have recently developed a new material feeder designated as Model 700N Batching Scale. The pilot model employs a unique rotary type feeder for charging a gateless tipping type weigh bucket. The weigh bucket is suspended from the scale and a cycle timer controls the automatic charging and discharging of the weigh bucket. The feeder is constructed so that there is no flow of the product through the feeder after the weigh bucket has been properly charged.

The scale is constructed having absolutely no knife-edge pivots. The scale platform, levers and weigh beam are supported by the plate leverage system. This patented feature enables the batching scale to handle millions of weighings, without any loss in accuracy or sensitivity of the scale. For this reason, it is especially suitable when handling products which are dusty, corrosive or abrasive.

The controls for this machine are electrical and pneumatic. The control box is furnished with automatic check-weighing lights, which will indicate the various phases of the scale weighing and discharging operation. The system is furnished with an automatic control and when the material runs low, an automatic alarm is sounded. Bulletins and survey sheets on Model 700N Batching Scales are available upon request. Inquiries should be sent directly to the attention of Mr. F. L. Thayer, Sales Director of the company.

CATALOGS RECEIVED

Hays Corporation, Michigan City, Indiana have issued a four-page color catalog 56-553-1. This catalog contains photos of the different types of Hays chemically operated CO_2 analyzers and recorders. Descriptions of the operation and sampling system are accompanied by drawings. Application, principle, features, available models and standard charts of these combustion meters are also covered.

Van Products Company. 5700 Old Ridge Road, Erie 7, Pennsylvania, have recently issued an interesting 20-page booklet which covers the subject of the moisture problem in compressed air systems. Entitled "Air, Water and Industry" sub-titled "Some compressed air problems and how to solve them," it describes moisture problems and what can be done about them. The company also has a companion brochure entitled "Moisture Control by Vi-Speed" which has been completely revised. It describes the improved method for removing moisture from air, hydrogen, nitrogen and natural gas lines. Both copies are available from the Vi-Speed manufacturer.

Clarence J. Marx Company, has just completed a bulletin AT135, describing the line of hand tachometers. Marx Company is the U. S. distributor for Smiths Industrial Instruments, Ltd.

J. J. Cope, Inc., 711 South 50 Street, Philadelphia 43, Pennsylvania have recently published three bulletins namely, an 8-page Catalog No. 853 describing supporting structures; Bulletin Standard 67A—16-page bulletin entitled, Cable Trough, New 70,000 Series with the Built-in Coupler and Bulletin 255, 12-pages on the "Instrof" System, with the Built-in Coupler." The bulletins may be obtained by writing T. J. Cope, Inc. for the first two, and bulletin No. 255 should be requested from Instrof Inc. at the same address.

Meriam Instrument Company, 10963 Madison Avenue, Cleveland 2, Ohio, have issued a new bulletin intended as a convenient, quick-reference guide to manometer-type instruments. The bulletin describes the four basic types of manometers, ranging from the simple U-tube to the ultra-precision models and provides principles to aid in the proper selection. The bulletin, No. G-10, is available upon request direct from the company.

General Electric Company, Detroit 32, Michigan have issued a publication GT-310 which covers the most effective cutting speeds for carbide tools, machine tools, machine tool horsepower requirements, how to determine shank size of single-point tools, carbide tool geometries, carbide grade selection and other technical topics. This 66-page catalog also includes price and specification information on standard brazed carbide tools, tool holders, standard carbide throw-away inserts, blanks for twist drills, dies, bushings, valve seats and many other applications.

Airmatic Valve, Inc., 7317 Associate Avenue, Cleveland 9, Ohio, have issued a quick reference guide to 17 different lines of Air-Control valves and accessories, for quick, easy selection of the right Airmatic Valve to fit the specific application.

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Milestones in Glass Progress

PHOTO COURTESY THE TOLEDO MUSEUM OF ART

1593 Painting glassware with opaque enamels was introduced into Germany during the second half of the sixteenth century. The idea came from Venice, and for about a hundred years it remained the favored type of decoration. This jug with pewter lid, dated 1595, shows two hounds chasing a red stag.

1890 Michigan Alkali Company, now a division of Wyandotte Chemicals Corporation (North Plant, above), was founded by Captain J. B. Ford to supply Soda Ash to the glass industry. Wyandotte has grown up with glass. Today, as in the past, it is a working partner, supplying technical assistance and raw-material chemicals to those great companies marking milestones in glass progress.

Wyandotte
CHEMICALS

Michigan Alkali Division, Wyandotte Chemicals Corporation
Wyandotte, Michigan • Offices in principal cities

Founded by a Glassmaker to Serve the Glass Industry

Approach to Forehearth Control . . .

(*Continued from page* 263)

Responsibilities of the Forming Department

In the combined approach to better forehearth control, the forming department plays an important part.

If this department does not properly maintain the equipment for which it is responsible, conditions can develop which the forehearth control system cannot correct. Maintenance responsibilities of the forming department should include:

(1) Proper setting and maintenance of the zero governor. Over a period of time this device will get out of adjustment, or the exhaust port may become clogged, making the governor inoperative.

(2) Proper setting and maintenance of the fuel-air ratio. This should be checked with a sight manometer.

(3) Checking the size of the orifice in the burner tips and their correct location in the different sections of the forehearth. This should be done at the time the forehearth sections are being repaired or rebuilt.

(4) Cleaning the burner tips, whenever necessary.

(5) Periodic cleaning of the Venturi tube and the filters upstream.

(6) Supervision of the proper setting of the skimmer block. This is important to prevent reversal action of the furnace from interfering with the operation of the forehearth controls.

Furnace Department Cooperation

Last, but not least, is the contribution of the furnace department to better forehearth control. Complete coverage of this subject is not within the scope of this article. Generally, however, the furnace is well instrumented and in many plants is automatically controlled. The furnace is the nucleus of the complete bottle forming system, and consistent cooperation between the furnace operator and the forming department makes for smooth, efficient system operation.

During the past forty years, the glass industry has pioneered in the use of instrumentation, quickly adopting any instrument that would improve the quality of the work. As forehearth control systems proved their value, the industry doubled its efforts to obtain a good tank level control system. With equipment now available to control tank level within ± 0.01 inch, the combination of forehearth and level control has improved quality.

Future Trends

In the near future, increasing plant capacity and improvements in processing will further extend the applications of instrumentation and automatic control on the forehearth. For example, increased speed of the forming machine and increased use of the double-gob technique will necessitate the measurement and control of actual gob temperatures. The extension of automatic temperature control to the stack dampers and cooling wind along with forehearth temperature is another development that can be expected, and the measurement and control of glass viscosity in the forehearth will further contribute to product quality. All of these developments point the way toward, ultimately, complete automation in the glass industry, through coordination and cooperation between instrument and operating personnel.

Research Digest . . .

(*Continued from page* 274)

high. The lower limit of desirable or permissible, apparent porosity would be zero, provided that this could be obtained in conjunction with a true porosity of about 20 per cent. This condition is necessary so that the refractories have a reasonably good resistance to thermal shock.

From the observations made, certain suggestions arise concerning the ways in which it may be possible to obtain the best combination of high mullite development, low mullite breakdown during firing and subsequent use and low apparent porosity values. These are: (1) magnesium carbonate or magnesium fluoride in amounts within the permissible ranges, according to the temperatures at which the refractories will be fired and used. (2) To add small amounts of alkali, such as Na_2O, either as the carbonate, nitrate, silicate or fluoride, these amounts being preferably smaller than the optimum amounts given in Table I for the various firing temperatures. (3) To fire the refractories thoroughly at the full temperatures at which they will be used, as far as this is possible. (4) In most, if not all cases, to use refractories based on the sillimanite composition rather than on the mullite composition, in order to obtain acceptable apparent porosities with total amounts of mineralizing agents, less than the amounts, would cause serious mullite breakdown during firing or subsequent use.

In deciding on the suitability, or otherwise, of clays from ordinary commercial sources, the quantities of the various alkalies and alkaline earths, which may be present, should be determined individually. To include these, without distinction, under the general description of fluxes gives a very imperfect indication of the effects which the fluxes may produce during the firing of the refractory mixture.

The presence of sulfates in clays for the manufacture of refractories is highly undesirable, partly on account of their effects in causing mullite breakdown and partly on account of their tendency to cause bloating. Chlorides are also undesirable, but cause less mullite breakdown and bloating than sulfates.

Ferric oxide, titania or manganese dioxide in commercial clays are not objectionable from the point of view of mullite breakdown provided that their amounts are less than the maximum permissible as given in Table I. Their mineralizing effects should be taken into account, however, in considering what amounts of other mineralizers should be added in order to obtain refractories with good mullite development, small rate of mullite breakdown and low apparent porosity. These oxides, if present, should be finely distributed through the whole mass of the clay, so that there are no vulnerable spots, due to the formation of entectics with silica and alumina and also because considerable mullite breakdown would occur in the immediate vicinity of large particles of the oxides, during firing.

Table I

Optimum and Maximum Permissible Proportions at Firing Temperatures of:

		Mullite Mixtures						Sillimanite Mixtures					
		2552° F		2732°F		2912° F		2552°F		2732° F		2912°F	
Oxide	Added as	Opt.	Max.	Opt.	Max.	Opt.	Max.	Opt.	Max.	Opt.	Max.	Opt.	Max.
Na_2O	Carbonate	1.0	2.0	1.0	2.0	1.0	1.0	1.0	2.0	1.0	2.0	1.0	1.0
	Nitrate	1.0	2.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0	2.0	1.0	1.0
	Silicate	0.75	2.0	0.75	1.0	..	..	1.0	2.0	1.0	1.0	..	..
	Fluoride	1.0	2.0	1.0	1.0	..	..	0.75	>1.0	0.75	>1.0	..	..
Li_2O	Carbonate	0.5	0.5	0.5	0.5	Nil	Nil	..	..	..	..	..	..
	Fluoride	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
K_2O	Carbonate	0.75	(1.5)	0.75	1.0	0.75	1.0	0.75	2.0	0.75	(1.5)	0.75	1.0
	Fluoride	0.75	2.0	0.75	1.0	..	..	0.75	2.0	0.75	2.0	..	..
MgO	Carbonate	1.0	3.0	0.75	2.0	0.5	2.0	..	..	..	..	..	..
	Fluoride	0.75	>3.0	0.5	3.0	0.5	2.0	..	..	0.5	(1.5)	0.5	(1.5)
CaO	Carbonate	1.0	2.0	1.0	1.0	..	..	..	..	..	..	..	..
	Fluoride	1.0	(2.5)	1.0	2.0	1.0	2.0	1.0	(4.0)	1.0	3.0	1.0	3.0
ZnO	Oxide	1.0	2.0	0.75	1.0	0.5	0.75	1.0	>2.0	0.75	>1.0	0.5	1.0
TiO_2	Oxide	0.75	>2.0	0.5	1.0	0.5	1.0	0.75	>2.0	0.5	>2.0	0.5	>2.0
MnO_2	Oxide	1.0	>2.0	..	..	0.75	1.0	0.75	>2.0	..	..	0.75	(1.5)
Fe_2O_3	Oxide	1.0	5.0	0.75	2.0	..	..	1.5	3.0	1.5	3.0	..	..
B_2O_3	Boric Acid ...	0.5	1.0	0.5	1.0	..	..	..	..	..	..	..	..

WALKUP PROMOTED TO NEW POST AT O-I

Promotion of Benjamin F. Walkup to chief mechanical engineer in the Administrative Engineering Department of Owens-Illinois Glass Company, a new post, has been announced by Oscar G. Burch, vice president in charge of engineering and research.

Mr. Walkup, who has been with the company since 1935, has been assigned to the Owens-Illinois Technical Center, Toledo, from the Alton, Ill., plant where he was plant engineer for the last three years.

He had previously served in O-I's glass container plants at Huntington, W. Va., Gas City, Ind., and Charleston, W. Va., and in the General Engineering Department.

HAZEL-ATLAS ELECTS DIRECTORS

The stockholders of Hazel-Atlas Glass Company, Wheeling, West Virginia, elected nine directors at the annual meeting: O. P. Decker of Chicago, H. G. Lewis and Karl Weaver of Wheeling were elected directors for the first time. H. W. Gee, W. W. Holloway, S. O. Laughlin, Jr., J. H. McNash, L. C. Paull, and B. H. Seabright were reelected directors

● The Hazel-Atlas Glass Company recently announced the formation of a Beverage Container Sales Department at its General Office in Wheeling, West Virginia. Mr. H. Carman Crago, who has long been associated with the company's sales activity, will manage the department.

Effect of Iron Compounds . . .

(*Continued from page* 261)

Table III
Color and Appearance of Glasses

G_1 Series — Electrolytic Iron

Standard Glass—no additions—clear glass only slight blue-green coloration.

Glass	Fe %	Appearance
G_1 –1	0.1	clear glass slight blue-green coloration
G_1 –2	0.2	clear glass slight blue-green coloration
G_1 –3	0.3	clear glass light blue-green coloration
G_1 –4	0.4	clear glass light blue-green coloration
G_1 –5	0.5	clear glass light blue-green coloration
G_1 –6	0.6	clear glass blue-green coloration
G_1 –8	0.8	blue-green color
G_1 –10	1.0	definite blue-green coloration
G_1 –12	1.2	dark blue-green coloration
G_1 –14	1.4	darker blue-green coloration
G_1 –16	1.6	very dark almost black color

This series showed an attractive bluish-green color.

G_2 Series — Red Iron Oxide Addition

G_2 –1	0.1	clear glass practically no coloration
G_2 –2	0.2	clear glass practically no coloration
G_2 –3	0.3	clear glass practically no coloration
G_2 –4	0.4	light yellow-green coloration
G_2 –5	0.5	light yellow-green coloration
G_2 –6	0.6	light yellow-green coloration
G_2 –8	0.8	definite yellow-green coloration
G_2 –10	1.0	definite yellow-green coloration
G_2 –12	1.2	dark yellow-green coloration
G_2 –14	1.4	dark yellow-green coloration
G_2 –16	1.6	darker amber coloration

This series showed a greenish-amber color.

G_3 Series — Magnetite Addition

G_3 –1	0.1	clear glass practically no color
G_3 –2	0.2	clear glass slight bluish-green coloration
G_3 –3	0.3	clear glass slight bluish-green coloration
G_3 –4	0.4	clear glass slight yellow-green coloration
G_3 –5	0.5	clear glass slight yellow-green coloration
G_3 –6	0.6	clear glass yellow-green coloration
G_3 –8	0.8	clear glass yellow-green coloration
G_3 –10	1.0	clear glass definite yellow-green coloration
G_3 –12	1.2	clear glass definite yellow-green coloration
G_3 –14	1.4	clear glass strong yellow-green coloration
G_3 –16	1.6	clear glass strong yellow-green coloration

This series was similar to the red iron oxide series only slightly more bluish in color.

III. DISCUSSION OF RESULTS

The coloration produced by red iron oxide (Fe_2O_3) additions and magnetite (Fe_3O_4) additions in these experiments was quite similar. The color of the magnetite (Fe_3O_4) glasses was slightly more bluish while the red iron oxide (Fe_2O_3) glasses was greenish amber This is quite evident in the colored picture (Fig. 1). The transmission in the extreme ultraviolet (320-380mμ) and the infrared region (850-1200mμ) different. The ultraviolet transmission in the Fe_3O_4 glasses was higher and infrared transmission lower than in the Fe_2O_3 glasses. This result suggested that Fe^{2+} was in greater amount in Fe_3O_4 glasses while Fe^{3+} was in greater amount in Fe_2O_3 glasses. The transmission between 400-700mμ was nearly the same in both glasses.

The tranmission of the glasses containing electrolytic iron (Fe) was considerably lower in the infrared (650-750mμ and the extreme infrared (800-1200mμ) regions than the transmission of the glasses containing Fe_2O_3 and Fe_3O_4. This difference was to be expected because a considerable amount of iron remained in the Fe^{2+} state, thus lowering the transmission in the infrared region. With high concentration of electrolytic iron (Fe) there seemed to be a strong coloring action on the glasses. The transmission between 400-700mμ) was considerably lower than for the other glasses.

In the series containing magnetite (Fe_3O_4), the glasses 12, 14, and 16, have lower transmission in the far-infrared region. This result suggested that at the higher concentrations of iron (higher than 1 percent) there was a tendency to obtain more Fe^{2+} in the glasses (Fe^{2+} decreases transmission in the infrared region). This trend was not observed in the Fe_2O_3 glasses, probably because there was a greater tendency to maintain the iron in the Fe^{3+} state.

In Table I the "Percent Ferrous State of Iron" has been calculated from the analytical data. These data, generally speaking, substantiated the results shown from the transmission curves. The ferrous state of iron was highest with the electrolytic iron glasses, lowest with the red iron oxide glasses, while the magnetite glass indicated an intermediate position. These values, in general, are low for such glasses and possibly indicate that the atmosphere obtained in the electric melting procedure was either oxidizing or neutral. It is also apparent that when red iron oxide and magnetite were used as a source of iron the "Ferrous State" appears to be greater at the lower concentrations of total iron. This was substantiated by Densem and Turner[4] and Wang and Turner[5].

In conclusion, it may be said that under the conditions of the experiment, bluish glasses were easier to obtain and maintain when electrolytic iron was used as a source of iron addition in the glass. Further, a higher "Percent Ferrous State of Iron" was maintained with these glasses. Magnetite and red iron oxide, on the other hand, appear to require some additional means of reduction under similar conditions of melting.

ACKNOWLEDGEMENT

The author is indebted to Mr. Yung Tao, of North American Refractories Company, Cleveland, Ohio, for preparation and analysis of the samples and invaluable technical assistance. Especial thanks are also due Miss Josephine Onderick, of the Kopp Glass Co., Swissvale, Pennsylvania, for the transmission studies, and to Mr. Elmer Prew of the Research Department of the New York State College of Ceramics for many helpful suggestions.

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Refractories of the future will come from Laclede-Christy laboratories—as have refractories now widely used. Laclede-Christy developments include CAST 400 bottom blocks, CAST FLUXTITE, castable refractories, HKP super-duty silica brick, cast pot clay and other products.

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Inventions and Inventors . . .

(*Continued from page* 273)

ing or otherwise applying a tin compound. The resistance of such film per unit square (surface film resistance) normally is substantially constant.

When the circuit is closed, electric current passes through the electroconductive transparent film 15 and heat is generated by virtue of the resistance of the film.

The electroconductive aids 17 have a lower resistance than the electroconductive film 15, thus the resistance between the main bus bars 14 is decreased. By proper arrangement of electroconductive aids, the film resistance between the bus bars may be controlled so that it is substantially the same througout the entire length of the bus bars. The electroconductive aids 17 may be of the same composition as the bus bars 14 or of a different electroconductive composition.

In general, the electroconductive aids or areas of higher electroconductivity are disposed so as to equalize flow of current over the panel to achieve reasonably uniform heating.

Where viewing closures for vehicles are to be provided, the base for the film normally is ordinary window or soda lime glass. Other refractory materials including borosilicate glass, china, mica, phosphate glass, silicon carbide, tungsten carbide, porcelain, stone or other refractory composition which melts at temperatures above 1150 to 1350° F. may be provided with electroconductive coatings in the same manner.

There were 13 claims and 5 references cited in this patent. 2,005,922, Stoekle, June 25, 1935; 2,021,661, Kisfaludy, Nov. 19, 1935; 2,134,870, Fruth, Nov. 1, 1938; 2,557,983, Linder, June 26, 1951; and 2,569,773, Orr, Oct. 2, 1951.

SYMPOSIUM ON QUALITY CONTROL IN INDIA

A very largely attended Symposium on Quality Control in the Glass Industry, the first of its kind, was held in India, December 21-22, 1955. The symposium seemed to stress the increasing science consciousness of this industry which now produces 120,000 tons annually. Approximately 25 papers, about half from other countries, particularly England and America were presented. Dr. Dudding, of British General Electric, elaborated on some of the more general papers by demonstrating control charts worked out using modern statistical methods ("The Collection, Presentation and Study of Data to Aid Industrial Efficiency"). Diagrams illustrated stable and unstable process; sampling distributions of defects, average, range for sample size; operating characteristics (i.e. probability of acceptance for different proportions defective), average sample, and maximum possible proportion defective after inspection. Specific applications were treated by Hanada (refractories), Murgatroyd (bottles). Thakur applied Poole's viscometer to the control of glass in automatic machines. J. Poole (USA) proposed to the Indian industry the deduction of compositional variations from two physical controls (e.g., density, softening point).

Color control was treated by Prasad (India), Kreidl and Pett (USA); the latter proposed the colorimetric space defined by R. Hunter for tolerance evaluation. Schwalbe (USA) and Garstang (UK) treated furnace design features affecting control. S. P. Varma describes the method of evaluating a compound fibre to control the expansion of one of its component glasses.

SURFACE APPOINTS CERAMIC SPECIALIST

Mr. E. T. Brady has been appointed ceramic engineer of Surface Combustion Corporation, Toledo, Ohio. He will be consultant to all the Industrial Division of the company in choice and application of refractory and insulation material.

During the past 13 years Mr. Brady contributed to the improvement of refractories for furnace linings and the development of special mixes for 'Surface' high temperature burner equipment.

T. E. Brady is a graduate of Indiana University a member of the American Ceramic Society and served as a member of the Toledo Technical Council.

The appointment of a ceramic specialist by Surface Combustion Corporation is in recognition of the importance of development and design of refractories from new materials to withstand the requirements of ever-increasing speed and temperature of modern industrial heating equipment.

BELLANO PROMOTED AT INTERNATIONAL MINERALS

William Bellano has been appointed to the newly created position of director, Mining & Minerals Exploration, International Minerals & Chemical Corporation, according to T. M. Ware, administrative vice president.

Mr. Bellano was production manager for International's Phosphate Chemicals Division, where his principal responsibility was the management of the company's new Bonnie phosphate chemicals plant. Prior to that, he was manager of general engineering services for the central engineering division, where he gained broad familiarization with the corporation's activities.

With over 19 years of mining experience both in the United States and abroad, he brings diversified mining, engineering and management experience to his new post.

AMERICAN POTASH APPOINTS DR. CLAPPER

Dr. Thomas W. Clapper has been appointed associate director of Research for American Potash & Chemical Corporation to head research facilities and activities at the company's Henderson, Nev., plant, it was announced by Joseph C. Schumacher, director of Research.

Clapper comes to American Potash & Chemical Corporation from Chemical Construction Company, a subsidiary of American Cyanamid Company, where he was plant manager of the Calera Cobalt refinery at Garfield, Utah. Previously, he had been a research chemist with American Cyanamid, later becoming head of the department producing sulfa drugs. He then was named technical director and, subsequently, general superintendent of the American Cyanamid Atomic Energy project at Idaho Falls, Idaho.

CORNING ELECTS THREE NEW VICE PRESIDENTS

R. L. Waterman

F. G. Hicks

Three vice presidents were elected by the Corning Glass Works board of directors following the annual meeting of stockholders held in the Corning Glass Center.

W. H. Armistead

The new officers are Dr. William H. Armistead, director of the company's Research and Development Division; Dr. John F. G. Hicks, general manager of the International Division; and R. Lee Waterman, general manager of the Consumer Products Division. All company officers and directors, other than those newly named, were reelected at the annual stockholders meeting.

Dr. Armistead has been associated with the Research and Development Division since 1941. He was manager of the melting department prior to his appointment as Division director in 1954.

Dr. Hicks joined the company as a chemist in 1938 and since three years' leave of absence with the Manhattan Project in 1943, he has been concerned with foreign operations. He was named general manager of the newly formed International Division in 1953.

Mr. Waterman was named general manager of the Consumer Products Division in 1955. He is also vice president of the company's subsidiary, Corning Glass Works of Canada Ltd.

Company officers who were reelected include Amory Houghton, chairman of the board; William C. Decker, president; George D. Macbeth, vice president and controller; Charles D. LaFollette, vice president and treasurer; John L. Hanigan, Russell Brittingham, John Carter and Thomas Waaland, vice president; Frederick H. Knight, secretary; Henry H. Sayles and William Sinclaire, assistant secretary; and C. Henry Kruidenier and Robert W. Foster, assistant treasurer.

Dr. Eugene C. Sullivan was reelected honorary chairman of the board. Dr. Arthur L. Day, William H. Curtiss, Harry M. Hosier, Jesse T. Littleton and William C. Taylor were reelected honorary vice presidents.

Members of the board of directors who were reelected

(*Continued on page 284*)

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Charles Eisler, Jr.
President

Corning Elects Vice Presidents . . .

(*Continued from page* 283)

are Amory Houghton, William H. Curtiss, William C. Decker, Amory Houghton, Jr., Arthur A. Houghton, Jr., Charles D. LaFollette, George D. Macbeth and Dr. Eugene C. Sullivan, all of Corning Glass Works; George Murnane, partner, Lazard Freres and Company, investment bankers, New York; Halsey Sayles of the law firm of Sayles and Evans, Elmira; Howard C. Sheperd, chairman of the board, The First National City Bank of New York; Walter Bedell Smith, vice chairman of the board, American Machine and Foundry Company, New York; and Boykin C. Wright of the law firm of Shearman and Sterling and Wright, New York.

NEW METHOD OF BONDING COPPER TO GLASS

Wildey C. Rickerson, president of The Haddam Manufacturing Company, 30 Rockefeller Plaza, New York, N. Y., announced that Edward W. Menke of their Yorktown Heights, N. Y., Laboratory has developed an entirely new method of bonding copper and copper alloys to glass. Patents have been applied for. The copper is bonded at a temperature in excess of the melting point of copper. One distinct advantage of this process is the fact that it integrally combines glass, one of the best insulators, with copper, one of the best conductors.

The bond between the copper and the glass is permanent. The copper will not peel nor discolor and will retain its bright copper color where it contacts the glass. The copper can be plated and soldered. It can be used in temperatures up to the softening point of glass before losing its bright color.

This process should have considerable value to the electrical and electronic industries. It also is possible to coat ceramics with copper and other metals by this same process. The uses should be extensive, and The Haddam Manufacturing Company is currently negotiating with several companies desirous of obtaining licenses for specific purposes.

HOUSEWARES SHOW TO FEATURE GLASS AND GLASSWARE SECTION

The first international housewares show will be held at the newly constructed New York Coliseum, June 25-29. More than 80 classifications of merchandise will be exhibited by leading manufacturers in the field. Buyers from all over the world are expected at the show. There will be a special section of glass and glasswares as a result of the great interest in glass and glasswares buyers and manufacturers, and the numerous inquiries for space. On May 1, Pennsylvania Glass Sand Corporation officially opened new sales offices in New York City and Tulsa, Oklahoma. The firm's Eastern sales offices are now located in the Chrysler Building in New York and their Western sales offices are in the recently completed Enterprise Building in Tulsa. General sales offices of the company will continue to be maintained at Two Gateway Center, Pittsburgh, Pa.

The new Tulsa office, will enable the company to expedite shipments to the Southwest and the West Coast. Larger sales quarters in New York will aid materially in giving the Eastern customers prompt, efficient service on their orders.

FIRST SYMPOSIUM ON THE ART OF GLASSBLOWING

The first Symposium on the Art of Glassblowing will be sponsored by The American Scientific Glassblowers Society (A.S.G.S.) and held at the Corning Glass Center, Corning, New York on June 8 and 9, 1956.

An interesting program has been arranged with well known authorities speaking on the technological and fabricating problems encountered during the construction of laboratory glass ware. Tours in and around Corning are planned for those attending the meetings and their families. All scientific glassblowers and those affiliated with scientific glassware are invited. Membership in the A.S.G.S. is not necessary.

The growing importance of this skill in the scientific field and the shortage of technically competent glassblowers poses a problem to this country's research effort. The American Scientific Glassblowers Society is an organization consisting of experimental and industrial glassblowers whose objectives are to further the technical advancement of this art. The Society was founded in 1952. Early meetings attracted glassblowers from the areas of Wilmington, Delaware, South Jersey, and Philadelphia, Pennsylvania. The organization, incorporated in 1954, now has 130 members who represent almost one hundred companies in the petroleum, pharmaceutical, nuclear, and electronic fields.

Local chapters are encouraged and necessary for the steady growth of the Society. This year was highlighted by the formation of the Pittsburgh Tri-State-Area Chapter. Interest on the West Coast may soon lead to chapter formations in that area of the United States.

Monthly meetings of the main body are held at various locations along the eastern seaboard and the activities of local chapter meetings are reported. The meetings include tours of glass factories and allied plants, technical papers on new techniques are delivered, devices to aid the glassblowers are shown, and problems relating to the betterment of glassblowers are discussed and acted on. Some present activities include work with the ASTM in establishing proper structural design of glass apparatus, making available fire-on decals of numbers, letters, graduations, etc. to small shops not equipped with etching and engraving equipment. A monthly "Newsletter" is distributed to the members, and the first edition of the Society's publication "Fusion" will appear soon. This rapidly expanding group, which has grown by word of mouth, could benefit the many glassblowers in universities and distant companies who are not as yet aware of the Society's existence.

Those interested in obtaining further information should contact the American Scientific Glassblowers Society, Box 784, Wilmington, Delaware.

● West End Chemical Company announces that construction is progressing on expansion of its sodium sulfate and salt cake facilities at its plant in Westend, California. Anticipated capacity will be approximately double their present 50,000 tons for these products by January 1, 1957. Primary factor in the decision to erect a second sulfate unit is the expansion of the Kraft pulp industry.

● John L. Alpert has been appointed to the position of executive vice president and general manager of Houze Glass Corporation, Point Marion, Pa.

CALUMITE...
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Help yourself to increased profits now!

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Acid Base Relationship . . .

(*Continued from page* 269)

to have different activation energies. W. A. Weyl and E. A. Hauser[6] consider the polymerization of the orthosilicic acid as a process in which the aggregation of the monomer by expansion of the coordination from 4 to 6 is relatively fast. This fast aggregation is followed by a slow condensation process so that the chemical and physical properties of the precipitate (silica gel) undergo gradual changes with time (aging).

When chromium hydroxide or ferric hydroxide are precipitated from a solution they are only poorly defined by the chemical formulae $Cr(OH)_3$ and $Fe(OH)_3$. Their properties depend upon the concentration and the temperature of the solutions from which they have been precipitated. These hydroxides are easily soluble in acids when freshly percipitated but become insoluble on aging. The rate of solution of a solid in an acid depends upon the polarizability of its anions. Oxygen ions which become "bridging" oxygens as the result of a dehydration of $Fe(OH)_3$ have lower polarizabilities because they are tightened by two Fe^{3+} ions.

The aging of these hydroxides improves the screening of the central cores. As a result, the acidity of these precipitates decreases with time. A fresh precipitate of aluminum hydroxide has a considerable adsorptive power for anions, e.g., acid dyes, but during aging some of these anions are released.

Heteropoly acids can form if protons of the water are replaced by two types of cations, both of which would produce acid properties by themselves. The Si^{4+} ion, in $Si(OH)_4$, for example, can improve its screening by forming a polysilicic acid, but in the presence of molybdic or tungstic acid it can improve its screening by sharing O^{2-} ions with the Mo^{6+} or W^{6+} cores. For these more interpenetrable cations it is energetically more favorable to be surrounded by the more polarizable O^{2-} ions than by the less polarizable OH^- ions. For this reason the compound $W^{6+}(OH^-)_6$ ages rapidly when precipitated in water changing from the white gelatinous precipitate into the yellow anhydrous tungstic oxide WO_3. This dehydration or aging of a compound $X^{n+}(OH)_n^-$ by changing its composition gradually in the direction toward the anhydrous oxide $^{Xn+}O^{2-}_{0.5n}$ take place even under water if the cation is of the non-noble gas-type. Thus, $Fe(OH)_3$ changes slowly into Fe_2O_3 but $Al(OH)_3$ does not. $Cu(OH)_2$ but not $Mg(OH)_2$ loses water readily. In the presence of silicic acid, the $W(OH)_6$ molecule copolymerizes with $Si(OH)_4$ molecules and forms complex-silico-tungstates. Compounds of this type contain O^{2-} ions in asymmetrical fields, e.g., Si^{4+} O^{2-} W^{6+} groups, and have chemical properties which differ from those of the end members, with respect to rates of reactions.

Whereas molybdic acid does not react with benzidine at a measurable rate, its reduction to molybdenum blue takes place instantaneously in the presence of traces of silicic, phosphoric or arsenic acid. Frequently, this loosening of the electronic system by asymmetry produces colors which differ from those of the end members.

(2) The Anionic Approach

In our approach to solid state chemistry we have followed the practice of crystal structure determinations and focused our attention upon the coordination number of the cation. The fact that NaCl molecules are stable only in the vapor phase but interact on cooling and form a crystal has been attributed to the screening demands of the Na^+ ions. The chemical reaction between Na^+ and Cl^- ions is terminated only when all cations are surrounded by anions and not just linked to one. This concept leads to a simple physical picture of polymerization and condensation reactions. However, there is another way to describe this process, namely, that NaCl molecules can lower their free energy by further tightening the Cl^- ions. This can be accomplished by bringing the anions into a symmetrical environment of cations. The interaction between Na^+ and Cl^- ions is a mutual one and, therefore, no difference exists between the two descriptions as far as the energy relations are concerned. In the one description the screening of the cation and in the other the stabilization and tightening of the anion is emphasized. One can look upon the acidity-basicity concept from two sides, namely, focusing one's attention upon the cations and speak about their screening by the anions or upon the anions and examine the degree to which they are tightened by the cations.

In our scheme (Table I) we derived acidic as well as basic solutions from neutral water by making the proper substitutions. All of these solutions contain H^+ ions and O^{2-} ions as major constituents. The easy way in which the degree of screening of protons can be measured by the hydrogen electrode or by the glass electrode makes it practical to use the proton and its screening as a basis for measuring the acidity of the system.

From the anionic point of view, one can explain the greater acidity of non-noble gas-like cations, e.g., Cu^{2+} and Zn^{2+}, as compared with noble gas-like cations of the same charge and similar size, e.g., Mg^{2+} and Ca^{2+}, on the basis of the different polarizabilities of the O^{2-} ions. The polarizability of an O^{2-} ion is decreased when it is exposed to the fields of strong cations and this tightening increases with the field strengths of the cations. However, cations with an incomplete shell are more interpenetrable for electrons and thus have a stronger tightening effect than less penetrable cations.

In fused salts, slags and glasses we cannot use a common cation such as the proton and, therefore, it becomes advantageous to shift the emphasis from the cation to the anion. Acidity corresponds to the degree to which the anions are tightened by positive fields. When we replace O^{2-} ions by F^- ions we frequently find that the acidity of the system is increased in spite of the fact that this substitution increases the anion to cation ratio.

Thus, H_2SiF_6 is a stronger acid than H_2SiO_3. The same is true for fluoroborates as compared with borates. The acidity of a system is inversely proportional to the polarizability of the anions.

A scheme for acid-base reactions which treats anions and cations on a par has been developed by V. Gutmann and I. Lindqvist[7]. The wide use of a solvent for performing chemical reactions led to a very general classification of the mechanism of acid-base reactions. V. Gutmann and I. Lindqvist postulated that acid-base reactions involve the transfer of one or more ions from one

(*Continued on page* 288)

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Acid Base Relationship . . .

(*Continued from page* 286)

molecular species to another and the ions which are transferred can be either cations or anions. This leads to a broad classification of what these authors called "ionotropic," processes into "cationotropic" and "anionotropic" reactions. Cationotropic processes are restricted to the proton as the only cation which can be transferred. With respect to "proton donating" and "proton accepting" molecules, their definition of acids and bases becomes identical with that used by Brönsted and Lowry. In their "anionotropic" reaction they include the concepts of H. Lux[8] who restricted himself to O^{2-} ions as the units which are transferred from one molecule to another. The concepts of H. Lux were derived for fused oxides but there is no reason why an O^{2-} ion should be treated differently than a F^- or an I^- ion. Thus V. Gutmann and I. Lindqvist speak of "fluoridotropic," "iodidotropic," etc., processes.

In order to include the solvent as a participant in acid-base reactions, hypothetical dissocation reactions were postulated, for example, for iodine as a solvent they write:

$$I_2 + I_2 = I^+ + I_3^-$$

and for SO_2 as a solvent they postulate the reaction:

$$SO_2 + SO_2 = SO^{2+} + SO_3^{2-}$$

From a practical point of view oxide systems are the most important. It becomes natural, therefore, to use the O^{2-} ions as the center around which one can develop an acid-base concept applicable to glasses and other fused oxide systems. This has been done by H. Lux. A base, according to H. Lux[8], is a compound which gives up O^{2-} ions to an acid compound, e.g.,

$$Ca^{2+}\ O^{2-} + S^{6+}O_3^{2-} = Ca^{2+}\ (S^{6+}O_4^{2-})^{2-}$$

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MAJOR ORGANIZATION CHANGES AT CORNING GLASS

Several major organization changes at Corning Glass Works were announced by William C. Decker, president.

Russell Brittingham, vice president, has been appointed director of purchasing, succeeding Frank S. Conable who has been named purchasing consultant.

Mr. Brittingham joined the company in 1944 as an administrative assistant to the director of research. He had been general manager of the Technical Products Division since 1946, including management of the Consumer Products Division from 1948 to 1951. In 1954, Laclede-Christy Division, H. K. Porter Company, Inc., he was elected a vice president of the company. Mr. Conable joined the purchasing department in 1920 as an invoice supervisor. The following year he was named assistant purchasing agent and in 1931 was appointed purchasing agent. He has been director of purchases.

Paul T. Clark succeeds Mr. Brittingham as general manager of the Technical Products Division. Julian H. Allen follows Mr. Clark as manager of manufacturing for the Division. John F. Culp succeeds Mr. Allen as controller of the Electrical Products Division.

Mr. Clark was first associated with the glass technology department in 1934. Following several years as a supervisor at Main Plant, in 1940 he was named assistant manager and then manager of the decorating department at the Charleroi, Pa., plant. Beginning in 1942 he served successively as general foreman of finishing operations and then of hand manufacture at Main Plant and production superintendent of Fall Brook. He was named manager of Fall Brook in 1945, manager of Pressware in 1951 and manager of manufacturing for the Technical Products Division in 1953.

Mr. Allen first served as plant accountant at Central Falls, R. I., in 1944. He was then named production superintendent at Central Falls, production superintendent at Albion, and manager of Fall Brook. In 1953 he was engaged in color television development and since 1955 has been controller of the Electrical Products Division.

Mr. Culp has been assistant controller of the Electrical Products Division since joining the company in 1955. Previously he had been associated with the U. S. Gypsum Company at Chicago.

Campbell Rutledge, Jr., has been appointed general sales manager of the Technical Products Division. John B. Ward, former director of design, succeeds Mr. Rutledge as sales manager of the New Products Division.

Mr. Rutledge joined the industrial sales staff in 1938. He was named assistant sales manager of the laboratory and pharmaceutical department in 1944, manager of standard products sales in 1948, assistant general manager of the Technical Products Division in 1951 and assistant general manager of the Electrical Products Division in 1953. He has been general sales manager of the New Products Division since 1954.

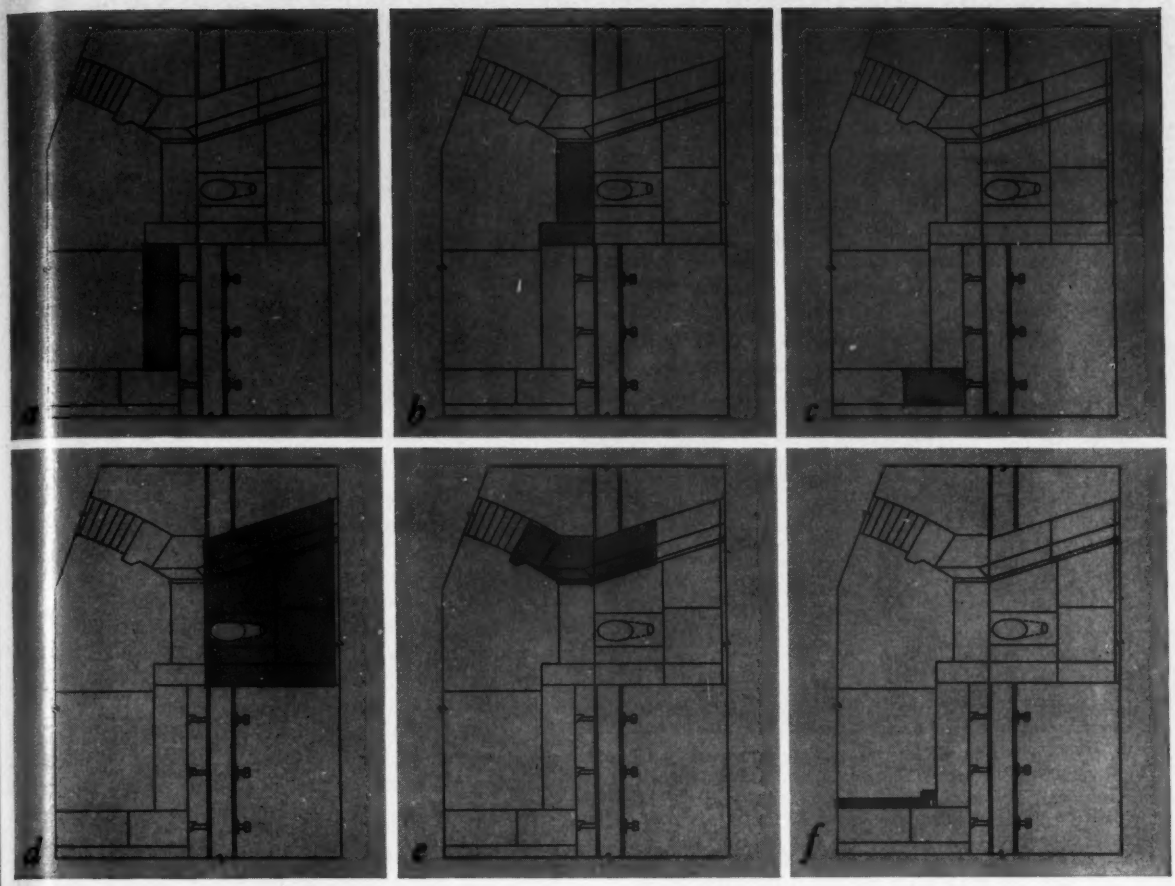
Richard M. Clifford, who has been manager at Albion, Mich., has been appointed assistant to the general manager of the Consumer Products Division.

Succeeding Mr. Clifford at Albion is LeRoy A. Amylon, former manager of the Danville, Ky., plant. A. Russell Arnold has been appointed plant manager at Danville and is succeeded as manager of the Fall Brook Plant at Corning by Paul A. Lang.

Other appointments include those of Lloyd D. Williams as production superintendent of Fall Brook; Leonard C. Liptak, plant quality and process engineer of the Pressware Plant at Corning, and Lee Goldman, manager of the Corning design department.

● Dr. William Dean McKee, Jr., a specialist in refractory materials and ceramic dielectrics, is now associated with Battelle Institute, Columbus, Ohio, as a member of the ceramics research staff. He was formerly employed by the General Electric Company at Owensboro, Kentucky, in receiving-tube engineering.

● B. B. Lanier, Jr., will be in charge of Export Sales for effective at once, according to an announcement by Rex D. Cross, the Division's General Manager.



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***b* BREAST WALLS and TUCK STONES.** MONOFRAX H blocks, made of a one phase material, have high heat shock resistance. They also provide excellent resistance to high temperatures, flame impingement and glass attack.

***c* BASE BLOCK AREA.** Resistance of MONOFRAX M blocks to undercutting and upward drilling assures firm side wall support.

***d* PORT NECKS.** Exceptional resistance of MONOFRAX H blocks to high temperatures, heat shock, flame impingement and attack by volatiles means longer port life, with little or no maintenance.

***e* CROWN-SKEW AREA.** MONOFRAX H skew, port arch and drip blocks provide extra strength. Drip blocks prevent silica rundown from reaching and, therefore, reacting with breast walls.

***f* BOTTOMS.** MONOFRAX M paving blocks resist both corrosion and erosion. Bottom life is extended and, averaging greater thickness, fuel is saved. Improved glass quality also is made possible.

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JAMESTOWN 1607-1957 PLANNED

Plans to open the internationally important working exhibit in 1957, commemorating America's oldest industry are fast materializing. The three consultants to the trustees of the Jamestown Glasshouse Foundation, Inc., are shown in a recent session where construction, melting, lehring operations, materials, supplies, controls and talent were on the agenda.

Officers of the foundation are: Harry H. Cook, president of the American Flint Glass Workers' Union of North America; C. W. Gustkey of Imperial Glass Corporation, president; W. F. Dalzell of Fostoria Glass Company, vice president; and, R. B. Tucker of Pittsburgh Plate Glass Company, secretary-treasurer.

First glass factory technical trio moving into details on Jamestown 1607-1957 factory demonstration. (Left to right): J. C. Harrington, National Park Service; Axel Ottoson of Imperial Glass Corp.; Art Willims, Fostoria Glass Co.

LITHIUM CORPORATION CURTAILS ITS SOUTH DAKOTA MINING OPERATION

H. W. Robers, president of the Lithium Corporation of America, Inc., announced plans to place its South Dakota mining operations on standby basis early next year, owing to surplus inventories of raw materials.

The company stated that the earlier short supply of spodumene, the lithium mineral, had been overcome by development of new sources and that adequate inventories of this raw material had built up to a level adequate for many months. Further production from its mines, therefore, is to be curtailed.

Formerly the main source of lithium minerals, the Black Hills area is now affected by competitive sources of supply which enjoy lower transportation costs and assured facilities for consistent and predictable production. Water supply has been a particular problem in the Black Hills the past two years.

HOUZE GLASS TO DEVELOP GLASS FIBER REINFORCED PLASTIC

Development of an improved glass fiber reinforced plastic will be undertaken by Houze Glass Corporation. This producer of sunglass lenses will develop the material under a research and development contract with the Navy Department, Bureau of Ordnance.

This project, which will include the drawing and evaluation of new types of glass fibers as well as the laminating of these fibers with plastic resins, will be directed by Dr. Albert H. Lasday, formerly of the Preston Laboratories. Armand L. Houze, Jr. will head the glass technology research.

PROMOTIONS AT O-I

J. Morehead R. H. Rugh

Owens-Illinois Glass Co. has announced changes involving key production managers.

Robert H. Rugh, manager of the glass container manufacturing plant at Charleston, W. Va., has been named manager of the Central Shops, Alton, Ill., succeeding Robert H. Levis, who has resigned to devote full time to personal interests.

John Morehead, supervisor at the Streator, Ill. plant and a veteran of 21 years service with O-I, will succeed Mr. Rugh as Charleston plant manager.

Mr. Rugh joined the glass company in 1937 and was on the engineering staffs of the Gas City, Ind. and Streator, Ill plants before he became plant manager at Clarion, Pa. in 1941. He was manager at Charleston since 1949.

Mr. Morehead served in various production assignments at O-I's Streator, Clarion, and Columbus, O. plants before he was named to the supervisory position.

BISHOP AND PITHER PROMOTED AT O-I

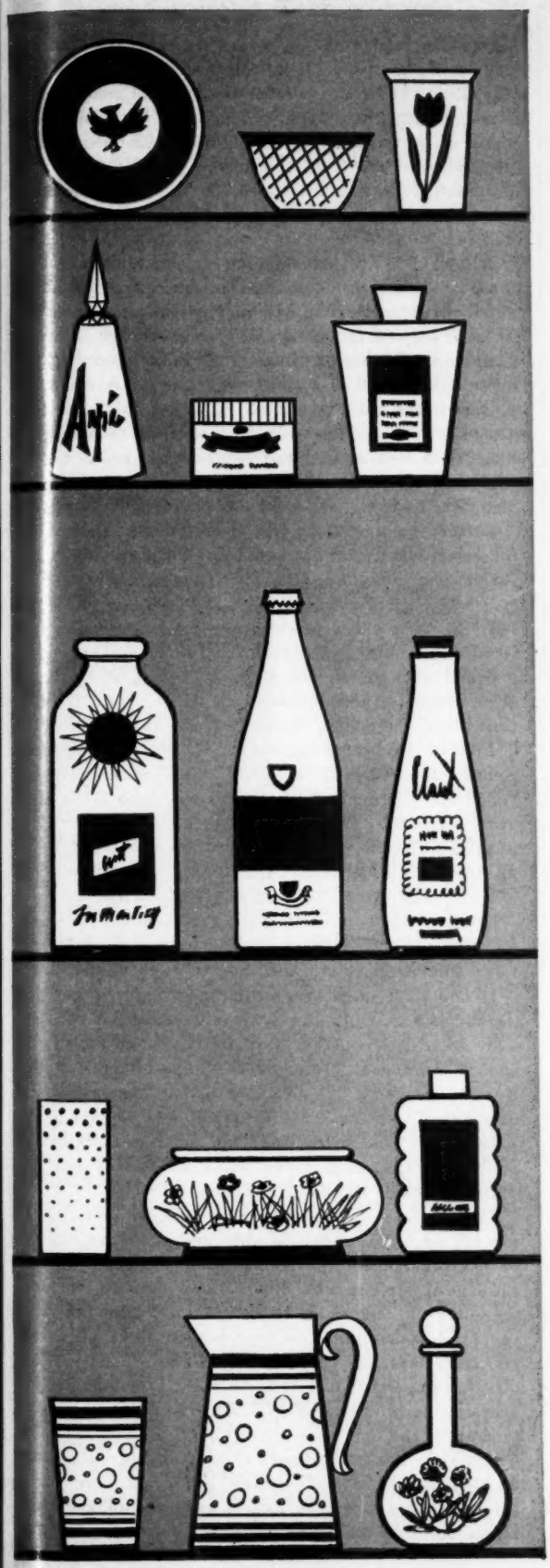
Promotion of Frederic L. Bishop, to director of the newly-created Glass and Furnace Technology Department for Kimble Glass Company, subsidiary of Owens-Illinois, has been announced by F. D. Pinotti, Kimble vice president and technical director.

The new department will be primarily responsible for activities at Kimble's plants in Columbus, O., Muncie, Ind., and Chicago Heights, Ill.

Dr. Bishop, with Kimble since 1953, previously was chief glass technologist in the Kimble laboratory at the Owens-Illinois Technical Center. He is a veteran of more than 20 years in the glass industry, having come to Kimble from American Window Glass Co., where he was a research physicist from 1933 to 1942 and director of research from 1942 to 1953.

Leslie F. Pither was named chief glass technologist and assistant director of the Glass and Furnace Technology Department. Mr. Pither, a glass technologist since 1936, joined Kimble in 1947 and has been assistant to the director of glass technology for the last two years.

● Transfer of Carl J. Snyder, plant engineer at the Fairmont, W. Va., plant of Owens-Illinois Glass Co., to the firm's general offices in Toledo, Ohio, has been announced by G. W. Cook, director of purchases.



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THE CANADIAN GLASS INDUSTRY

There has been a decline in all directions in Canada's glass and glass products industry, according to the latest annual survey of such operations by the Canadian Government which has just announced that the gross selling value of the products of this industry dropped to $67,988,201 in 1954 from the record $72,910,166 in the preceding year, a decrease of 6.7%, with the value added by manufacture dropping to $38,043,507 from $40,124,444.

A total of 117 plants including glass manufacturers and those producing products from finished glass operated in 1954 in contrast to the 118 in previous year, including in latest year 62 in Ontario, 37 Quebec, 9 each in British Columbia and other provinces, while in the preceding year these were 61, 38, 9 and 10 respectively. Average employees in the industry fell to 7,526 from 7,830 and their earnings dropped to $24,698,809 from $24,978,847, though the cost of fuel and electricity at works rose to $4,315,580 from $4,232,924. However, cost at plants of materials used dropped to $26,606,278 from $28,552,798.

Factory shipments by the glass industry showed the following, (figures in brackets being for preceding year:)

Cut and Bevelled Glass Division: Mirrors: Plate glass $2,870,779 ($3,512,629), Sheet glass, $93[illegible]523 ($1,126,594); Other products of glass: Bevelled or polished edge plate, $1,018,538 ($1,136,253), Bevelled or polished edge sheet glass, $385,303 ($394,286), Leaded glass, including memorial windows, $199,229 ($213,[illegible]64), Cut glass (tumblers, bowls, etc.), $1,047,687 ($1,021,361), Decorated glassware (including engraved, etched, sand-blasted, applied color, etc.), $283,040 ($343,938), Druggists', physicians' and laboratory glassware, $576,312 ($550,511), Other glass products, $16,213,077 ($18,550,130); Receipts for custom and repair work, $288,778 ($97,198); All other products, $1,886,572 ($1,614,997); Total, $25,702,838 ($28,561,761).

Pressed, Blown and Drawn Glass Division: Pressed, blown and drawn glass, including bottles, sealers, ovenware, window glass, etc., $42,285,363 ($44,348,405).

Of the 7,526 employees in the glass industry in 1954, the supervisory and office workers included 859 men and 476 women, production workers 5,194 men and 997 women, whereas in preceding year supervisory and office workers included 909 men and 528 women as well as production workers 5,394 men and 999 women of the 7,830 total. The supervisory and office workers earned $5,225,225 against previous year's $5,268,094 and production workers $19,473,584 against $19,710,753.

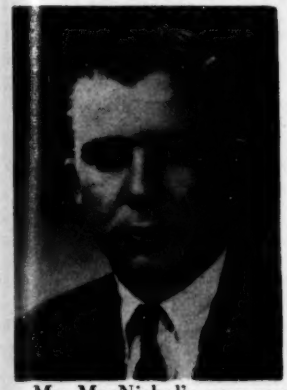
There was a downward trend in both imports and exports since the imports of glass and glassware dropped to $33,570,483 from $37,112,273 and the exports fell to $1,368,062 from $1,982,805. Major imports included the following, (figures in brackets being for the preceding year): Glass demijohns, carboys, bottles, flasks, phials and jars, and balls, not cut, $5,521,463 ($5,792,262); Plate glass, n.o.p., $5,059,674 ($6,348,832); Common and colorless window glass, $3,007,522 ($3,298,572); Glass tableware and cut glassware, n.o.p., $2,514,635 ($2,492,635); High thermal shock-resisting glassware, $2,378,342 ($2,532,828); Plate glass, not bevelled, in sheets or panes exceeding 7 sq. ft. each and not exceeding 25 sq. ft. each, n.o.p., $2,209,235 ($2,499,067); Manu-

factures of glass, n.o.p., $1,929,307 ($2,106,842); Incandescent lamp bulbs and glass tubing, etc., $1,869,973 ($2,326,778); Hollow shapes of glass and of plastics, molded, for the manufacture of electric light fixtures, $1,378,941 ($1,369,114); Glass in sheets and bent plate glass, n.o.p., $1,045,045 ($1,291,026).

Exports included the following (figures in brackets being for previous year): Common and colorless window glass, 7,851,577 (13,780,994) sq. ft., $852,038 ($1,317,769); Lenses of glass, rough or finished, $237,890 ($276,484); Glass and glassware, n.o.p., $160,768 ($234,949).

There was a sharp rise in capital and repair expenditures in the glass and glass products industry in 1954, rising to $11,830,000 from previous year's $7,957,000. Capital expenditures jumped to $5,985,000 from $2,809,000, including $2,797,000 against only $696,000 for construction and $3,188,000 against $2,113,000 for machinery and equipment, while repair and maintenance expenditures increased to $5,845,000 from $5,148,000, including $572,000 against $565,000 for construction and $5,273,000 from $4,583,000 for machinery and equipment.

MACNICHOL NAMED TO L.O.F. PRODUCTION POLICY COMMITTEE



Transfer of George P. MacNichol, III, from Thermopane to the production policy committee of Libbey-Owens-Ford Glass Company was announced recently by Curtis W. Davis, executive vice president, in charge of production.

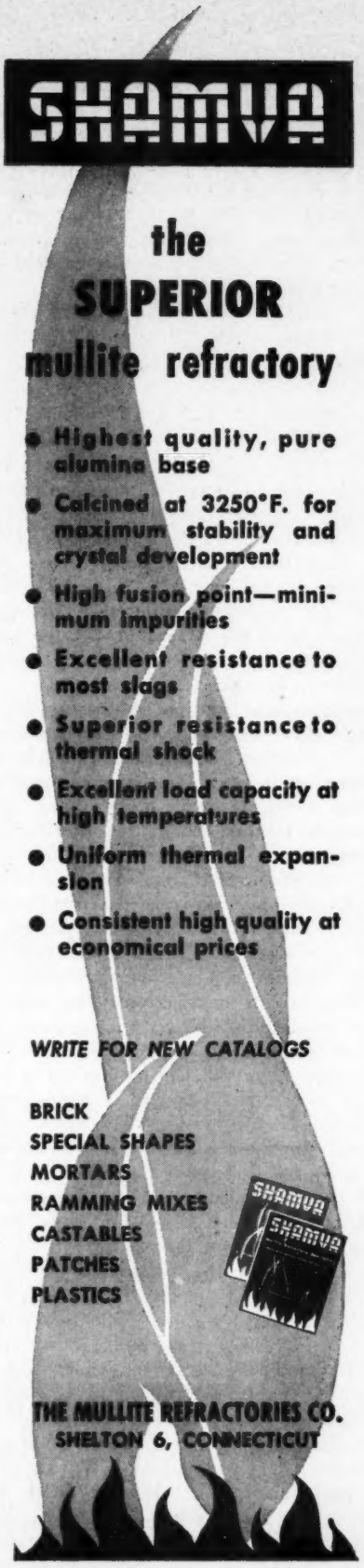
The transfer was made effective when Mr. MacNichol joined the company's general offices in the National Bank Building.

Mr. MacNichol's new responsibilities as a staff member of the production policy committee includes special assignments on material costs and usage. Mr. Davis explained that this would encompass membership on the company's materials committee, resident work on furnace rebuilds, participation in maintenance surveys of plant properties, study of storeroom practices and end use of materials at the plants as well as traffic and purchasing procedures.

For the last two years an assistant manager of the Thermopane plant, Mr. MacNichol has been associated with the manufacturing department of LOF for eight years. Prior to becoming a member of the Thermopane operating management six years ago, he was on special assignments at other factories. He also was responsible for organizing and supervising the company's Electrapane department.

Mr. MacNichol is a graduate of Yale University and had three years service with the Naval Air Corps as an ensign prior to joining Libbey-Owens-Ford. His home is on the East River Road, Perrysburg.

Charles Shelly, who became assistant manager at Thermopane with Mr. MacNichol in 1954, will continue in that capacity.



Current Statistical Position . . .

(*Continued from page* 275)

● Revised figures for glass container production and shipments for 1955, just received, show even higher totals than reported in the March, 1956 issue of THE GLASS INDUSTRY.

The year 1955 was a peak year in glass container production and domestic shipments. Production was a record high 139,500,000 gross, outdoing by 8 per cent the previous peak year, 1953. Domestic shipments were 11 per cent higher than the best year. Stock on hand was slightly less than at the close of the previous year.

The above summary was compiled from data received from 39 companies, manufacturing machine made glass containers.

REFRACTORIES SYMPOSIUM AT ALFRED UNIVERSITY

A refractories symposium, designed primarily for undergraduates but open to others interested in the field, will be held June 11-29 at the New York State College of Ceramics at Alfred University according to an announcement by Dean John F. McMahon.

The three-week program will be devoted to the field of refractory high-temperature materials. Forty-three guest lecturers will be on the AU campus for the symposium. These will include leading engineers and scientists currently active in the refractory industry.

The comprehensive study of refractories will consider such phases as raw materials, processing and firing, properties and application. Undergraduates will receive three academic credits by attending the lectures and passing a final exam. Graduate credit of two hours is allowed.

A three-man planning committee is handling program arrangements for the symposium. Chairman of the committee is Dr. Milton A. Tuttle, Assistant Professor of Ceramic Engineering. He is being assisted by James R. Tinklepaugh, Director of the Air Force Research Project in the College of Ceramics, and Dr. Willard J. Sutton, Associated Professor of Ceramic Engineering.

Dr. Tuttle reports that persons other than students interested in attending the refractories symposium are invited and welcome. Requests for detailed information regarding the program should be directed to Dr. Tuttle at the New York State College of Ceramics, Alfred University, Alfred, N. Y.

The June symposium will be the seventh annual course sponsored by the College of Ceramics at AU. Other symposia have been held on enamels, whitewares, structural clays, abrasives and glass. This is the second year that refractories are being featured.

Guest Lecturers at the symposium will be: W. J. Sutton, State University of New York College of Ceramics, Alfred University; R. A. Moffet, North American Refractories Co.; L. R. Armstrong, Findlay Clay Products; J. H. Kruson, Big Savage Refractories Corp.; A. R. Lesar, A. P. Green Fire Brick Co.; E. R. Crandall, Mullite Refractories Co.; C. A. Brashares, Harbison-Walker Refractories Co.; C. B. Shelley, General Refractories Co.; R. R. Rhodes, E. J. Lavino & Co.; J. W. Craig, Canadian Refractories, Ltd.; F. W. Schroeder, North American Refractories Co.; John Puckett, Leeds & Northrup Co.; J. A. Bowman, Minneapolis-Honeywell Regulator Co.; G. J. Easter, Electro Refractories & Abrasives Co.; L. H. Juel, Great Lakes Carbon Corp.; H. E. White, Lava Crucible Refractories Co.; A. J. Hathaway, Titanium Alloy Mfg. Div., National Lead Corp.; O. J. Whittemore, Jr., Norton Company; W. R. Kerr, Armstrong Cork Co.; R. K. Hursh, University of Illinois; F. E. Lobaugh, Universal Atlas Cement Co.; J. T. Robson, Allied Engineering Div., Ferro Enamel Corp.; B. Hooper, Babcock & Wilcox Co.; J. R. Johnson, Minnesota Mining & Mfg. Co.; J. R. Tinklepaugh, State University of New York College of Ceramics, Alfred University; C. E. Jewart, Bethlehem Steel Co.; H. M. Kraner, Bethlehem Steel Co.; E. F. Osborn, Pennsylvania State University; S. Mrozowski, University of Buffalo; R. B. Sosman, Rutgers University; L. J. Trostel, General Refractories Co.; E. A. Thomas, Charles Taylor Sons Co.; D. E. Emhiser, Pittsburgh Plate Glass Co.; R. S. Arrandale, Thatcher Glass Manufacturing Co.; R. K. Smith, Corning Glass Works; R. E. Birch, Harbison-Walker Refractories Co.; S. M. Phelps, Refractories Fellowship, Mellon Institute; C. L. Norton, The Babcock & Wilcox Co.; M. J. Buerger, M.I.T.; W. B. Crandall, State University of New York College of Ceramics, Alfred University.

APPOINTMENTS AT OWENS-CORNING FIBERGLAS CORP.

A. C. Siefert

L. P. Biefeld

Dr. A. C. Siefert has been appointed director of research of Owens-Corning Fiberglas Corporation, it was announced by Games Slayter, vice president, research and development. At the same time, Mr. Slayter announced the appointment of Dr. L. P. Biefeld as technical director of the company's Research Division, whose headquarters are at Newark, Ohio.

Dr. Siefert joined Owens-Corning research laboratories in 1942 and became chief glass technologist in 1946. He is chairman of the Glass Division of the American Ceramics Society. Prior to his present appointment, he was manager of research.

Appointment of Harrison C. Blankmeyer as manager of the research laboratories of the Textile Products Division of Owens-Corning Fiberglas Corporation was announced by John H. Thomas, vice president of the company and general manager of the division.

In his new position, Mr. Blankmeyer will supervise efforts directed toward developing new Fiberglas textile products and processes and improving existing ones. He will be headquartered at Owens-Corning's textile laboratories at Ashton, R. I.

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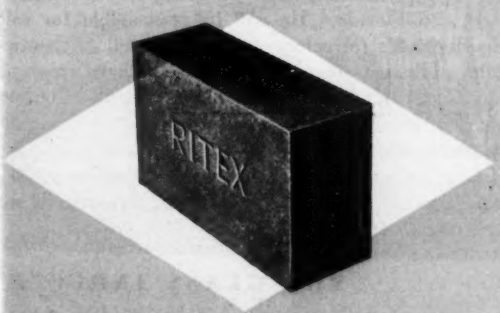

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DIAMOND ALKALI ADDS TWO DIVISIONS

Diamond Alkali Company, Cleveland, Ohio, has announced the divisionalization of management responsibility and administrative functions covering its nationwide operations by establishing two additional autonomous units, effective February 1, it was announced by Raymond F. Evans, chairman and chief executive officer.

Through this divisionalization program, initially launched in January 1953, Diamond has set up five separate autonomous divisions: Plastics, Chromium Chemicals; Silicate; Detergent; Calcium, Chlorinated Products; and Cement Coke.

The new divisions, named the Electro Chemicals Division and the Soda Products Division, will function autonomously in the same manner as Diamond's five other previously created divisions, Mr. Evans said. Both groups will assume for their respective organizations all sales, research and plant manufacturing activities, with performance responsibility in each unit to be vested in the division general manager.

Frank Chrencik, formerly works manager of Diamond's Deer Park Plant at Houston, Texas, for the past two years, becomes general manager of the Electro Chemicals Division.

Henry B. Clark, manager of the company's New York-New England Branch Sales Office since 1948 has been named general manager of the Soda Products Division. Both men will make their headquarters at Diamond's national headquarters in Cleveland.

CORNING GLASS PLANS TO ENLARGE FACILITIES

Plans to enlarge facilities for the manufacture of glass electronic components in the Corning Glass Works plant at Bradford, Pennsylvania, were announced by John L. Hanigan, vice president and general manager of the company's Electrical Products Division. The Bradford plant was established by Corning in 1944 and has been in continual operation since that time.

Approximately 20,000 square feet of additional floor space has been acquired by the company in the Bradford area. Necessary alterations are now being carried out.

W. A. Ende, presently in charge of manufacturing operations for the Components Department will now be located in Bradford, where he will assume the position of plant manager of the enlarged operation.

Frank L. Witter, in charge of Bradford operations for the new Products Division, assumes increased production responsibilities in the Bradford operation.

FMC CHEMICALS PERSONNEL CHANGES

Chemical Divisions of Food Machinery and Chemical Corporation announced the following new appointments:

John Rivoire has joined the development department of Westvaco Mineral Products Division, Food Machinery and Chemical Corporation, in New York, as manager of market research. Formerly, he was associated with Pfizer and Company.

R. M. Hoyer has been appointed district sales manager, Westvaco Chlor-Alkali Division for the Southern and Ohio Valley territory, with W. M. Clark working under him. Mr. Clark will continue as Southern sales representative, and Joseph Green has joined the staff of F. M. C., Chemical Div., central research laboratory.

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M.I.T. SPECIAL SUMMER PROGRAM

A special summer program 3.709 "Theory and Practice of Ceramic Forming" has been announced by the Massachusetts Institute of Technology.

The summer program will be held from Monday, July 16 through Friday, July 27, 1956. The session will cover a wide variety of ceramic fabrication processes from both theoretical and practical points of view. The theory basic to various processes will be considered, giving particular attention to recent developments and the probable direction of future developments. Current technology will be considered with particular attention given to controls required and problems encountered in practice. The program will consider forming operations applicable to electrical ceramics, special refractories, ferrites, abrasives, coatings, ferroelectrics, white wares, cermets and other products. However, it will consider the forming operations as unit processes rather than as technology of particular products. Requests for application forms should be made through the Office of the Summer Session, Room 7-103, Massachusetts Institute of Technology, Cambridge 39, Massachusetts. Tuition is $200.

KAISER APPOINTMENTS

Fred Lohse has been appointed technical assistant to the manager of the Chemical Division of Kaiser Aluminum & Chemical Corporation.

Mr. Lohse will be in charge of coordinating technical planning of the Chemicals Division, and has had more than twenty years' experience in chemical engineering and related fields. He has held various positions related to technical project development activities with Kaiser, including his most recent post assistant to the vice president in charge of research and development.

Samuel T. Johnston will represent the Chemicals Division as a salesman in the southern states of Tennessee, Mississippi, Alabama, North Carolina, South Carolina, Georgia and Florida. He will be responsible for sales of this division's refractory products as well as chemical alumina and magnesia products in the southern area.

Carl Snider has been transferred to Detroit, Michigan, where he will represent the Chemicals Division in the Michigan and northwest Ohio area. Prior to this appointment, he served as a sales engineer for the division in Oakland, California. Mr. Murray Schmidt will succeed Snider in Oakland.

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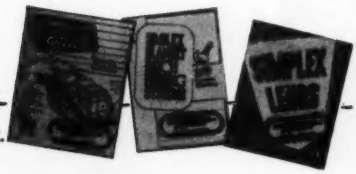

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the glass industry

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Published by

OGDEN PUBLISHING COMPANY 55 WEST 42nd STREET, NEW YORK 36, N. Y.

JOHN T. OGDEN *and* KATHERINE W. OGDEN, Owners

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Midwest Representative: Macintyre-Simpson & Woods
Chicago office: 75 E. Wacker Drive; Cleveland office: 1900 Euclid Ave.

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The GLASS INDUSTRY, Vol. 37, No. 6, June, 1956. Published monthly by Ogden Publishing Company, 55 West 42nd Street, New York 36, N. Y. Subscription $4.00 a year. Canada and foreign, $5.00. Single copies 40 cents domestic, 60 cents Canada and Foreign. Issues over three months old 60 cents; over one year, $1.00. Second class mail privileges authorized at New York, N. Y.